Ipomopsis spicata (Nutt.) V. Grant ssp. *robruthiorum* Wilken & Hartman (spiked ipomopsis): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

January 24, 2005

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Peer Review Administered by
Center for Plant Conservation

Pokorny, M.L. (2005, January 24). *Ipomopsis spicata* (Nutt.) V. Grant ssp. *robruthiorum* Wilken & Hartman (spiked ipomopsis): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/ipomopsisspicatassprobruthiorum.pdf [date of access].

ACKNOWLEDGEMENTS

This technical conservation assessment was completed with the assistance of many individuals. I would like to thank the Wyoming Natural Diversity Database, especially Tessa Dutcher and Bonnie Heidel, for their help and for making their files and records available. I would like to thank the Central Wyoming College Herbarium, the Rocky Mountain Herbarium, the Wyoming Natural Diversity Database, and the University of Northern Colorado Herbarium for sending information from plant specimen labels and occurrence records. This type of information helped to determine the diversity of the taxon and its current range. The conversations and information received from Kent Houston, Shoshone National Forest Ecologist, were essential for making inferences on current and future conservation needs. I appreciate the thorough reviews of Dr. Dieter Wilken and Beth Burkhart.

AUTHOR'S BIOGRAPHY

Monica L. Pokorny received a B.S. degree (with honors) in Biology with an emphasis in Botany, and a minor in Wildlife Biology, from the University of Montana. After completion of her bachelor degree, she worked with the USDA Forest Service and The Nature Conservancy on forest inventory and analysis, forest fire fuel planning, and monitoring rare, endangered, and sensitive plant species. Her first professional position was as a Research Biologist for the Craighead Wildlife-Wildlands Institute, where she was involved in the development of an improved land cover classification and grizzly bear habitat assessment of the Salmon-Selwey ecosystem using Landsat TM imagery and wilderness botanical survey. She obtained a M.S. degree in Land Resources and Environmental Sciences from Montana State University. Her Master's research focused on quantifying the vegetative species richness and densities in a grassland plant community; determining the ability of functional group diversity at resisting invasion by a nonindigenous invader; and quantifying the ecological role of indigenous and nonindigenous functional groups in a grassland ecosystem. Monica continues to work with invasive nonindigenous plants and rare plants. She has written a botanical guide for the noxious weeds of Montana and works on contract to map the location and abundance of rare, sensitive, and invasive plant species. Monica is currently developing a Restoration Program for Montana State University and works as a consultant for *Garcia and Associates*, an environmental consulting company in Bozeman, Montana.

COVER PHOTO CREDIT

Ipomopsis spicata ssp. *robruthiorum* (spiked ipomopsis). Photograph by Walt Fertig, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *IPOMOPSIS SPICATA* SSP. *ROBRUTHIORUM*

Status

To characterize the relative rarity or endangerment of a given species, NatureServe assigns global status ranks. *Ipomopsis spicata* ssp. *robruthiorum* receives a rank of G5T2; as a species it is globally secure (G5), but the subspecies is globally imperiled (T2) (NatureServe 2004). The USDA Forest Service (USFS) Region 2 does not designate *I. spicata* ssp. *robruthiorum* as a sensitive species (USDA Forest Service 2003). The global distribution of this subspecies is limited to the Shoshone National Forest; therefore, the Bureau of Land Management, National Park Service, and tribes within Wyoming give no official attention to *I. spicata* ssp. *robruthiorum* (Fertig et al. 1994, Heidel personal communication 2004). The Wyoming Natural Diversity Database lists *I. spicata* ssp. *robruthii* (synonym for *I. spicata* ssp. *robruthiorum*) as endemic to Wyoming, gives it a medium conservation priority, and ranks the subspecies as imperiled in the state (S2).

Primary Threats

Currently, so little is known about *Ipomopsis spicata* ssp. *robruthiorum* that threats to this taxon are not well understood. The discussion of threats in this document is based mainly on conversations with USFS biologists and on the biological and habitat characteristics of the taxon that increase its vulnerability to reductions in abundance and distribution, such as its limited range, small isolated populations, and the climatic variability of its habitat.

Global warming and genetic characteristics are the primary threats to *Ipomopsis spicata* ssp. *robruthiorum*. Increased temperatures may cause increased competition in the subalpine and alpine zones and/or a reduction in suitable habitat. Genetic characteristics that could affect the long-term survival of *I. spicata* ssp. *robruthiorum* include the potential adverse effects of inbreeding, genetic drift, or outbreeding depression.

All 16 known occurrences of *Ipomopsis spicata* ssp. *robruthiorum* are located on USFS lands. Two occurrences are on land managed for multiple use, and 14 occurrences are on land managed for wilderness. Recreational use by hikers, all-terrain vehicle (ATV) users, and campers occurs in the vicinity of some occurrences of this taxon, and this poses a moderate threat from trampling. The effects of trampling are especially noticeable within the Windy Mountain occurrence, adjacent to a hiking trail. Off-road travel by ATVs threatens occurrences near Carter Mountain. The spread of exotic invasive species is another moderate-level threat. Invasive species could increase competition and displace native plants, including this taxon. Pesticides used in the vicinity of *I. spicata* ssp. *robruthiorum* to control invasive plants could also impact the taxon and/or its pollinators through direct contact or drift. *Ipomopsis spicata* ssp. *robruthiorum* occurs in active livestock grazing allotments on the Shoshone Forest, but grazing at current levels appears to be a low-level threat. However, the effects of grazing or trampling by herbivores have not been studied. Minimal mining activity occurs on the Shoshone Forest, and this is currently considered to be a low-level threat. The habitats that support *I. spicata* ssp. *robruthiorum* are not conducive to large-scale timber harvests. Therefore, impacts from timber harvest are a low-level threat. Overall, fire is thought to pose a low-level threat to the taxon because it is infrequent in the taxon's habitat; however, the effects of a wildfire or a prescribed fire have not been studied. Another low-level threat is the harvest of plants of this taxon by collectors seeking plants for rock gardens.

Primary Conservation Elements, Management Implications and Considerations

Ipomopsis spicata ssp. *robruthiorum* is endemic to volcanic soils and substrates from 6,650 to 13,140 feet in elevation in the Absaroka Mountains of Park and Hot Springs counties in northwestern Wyoming. Many portions of the Absaroka Mountains have been floristically surveyed; however, no formal range-wide survey has been conducted for *I. spicata* ssp. *robruthiorum*. A detailed field survey for *I. spicata* ssp. *robruthiorum* might increase the number of known occurrences as well as provide additional information on the taxon's status including its distribution, population size, and habitat requirements. Long-term monitoring for *I. spicata* ssp. *robruthiorum* could provide additional information on the habitat, threats (e.g., disturbance, invasive species, global warming), population trends, life-history, and demography of this taxon. Initiation of long-term monitoring would also give land managers better knowledge of the impacts of disturbance (both natural and human-caused) and of the taxon's biology and community

ecology. This information is essential for conducting land management activities while protecting *I. spicata* ssp. *robruthiorum* as little is currently known about its biology and ecology. Management of this taxon would benefit from the results of a population viability analysis and studies of the taxon's pollination ecology as well. It would be useful to know the size of the population needed to maintain genetic diversity, and if current reproductive output is sufficient to maintain population levels. This information is critical for conservation and would contribute to more effective management decisions relative to the persistence of this taxon.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Ipomopsis spicata* (Nutt.) V. Grant ssp. *robruthiorum* Wilken & Hartman (spiked ipomopsis) has been included in the Species Conservation Project because of its limited range, the small number of known occurrences, and the limited knowledge of its biology and ecology. *Ipomopsis spicata* ssp. *robruthiorum* was formerly listed as a sensitive species in Region 2. It was not included on the Region 2 sensitive species list in 2003 because threats appear to be low (Warren et al. 2003). However, it is currently under consideration for other emphasis species lists at the forest level (Warren et al. 2003). Within the National Forest System, a sensitive species is a plant or animal species whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers, density, or habitat capability that would reduce its existing distribution (FSM 2670.5 (19); USDA Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology and ecology of *Ipomopsis spicata* ssp. *robruthiorum* throughout its range, which is completely within Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of selected species, based on existing scientific knowledge. The assessment goals limit the scope of the work to: 1) critical summaries of existing scientific information, 2) discussion of broad implications of that knowledge, and 3) outlines of information needs. The assessment does not develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, the assessment cites management recommendations proposed elsewhere, and if these have been implemented, the assessment examines their level of success.

Scope

The *Ipomopsis spicata* ssp. *robruthiorum* assessment examines the biology, ecology, conservation status, and management of this taxon with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. In addition, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *I. spicata* ssp. *robruthiorum* in the context of the current environment, rather than under historical conditions. The evolutionary environment of the taxon is considered in conducting the synthesis, but it is placed in a current context.

In producing this assessment, an extensive literature search was performed to obtain material on *Ipomopsis spicata* ssp. *robruthiorum*. The literature review included refereed literature, non-refereed publications, theses and dissertations, research reports, data accumulated by resource management agencies, herbarium specimens, and regulatory guidelines. Not all published and unpublished materials on *I. spicata* ssp. *robruthiorum* were considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Unfortunately, refereed literature on *I. spicata* ssp. *robruthiorum* is scarce. Non-refereed publications or reports were used when they contained information that was unavailable elsewhere, but these sources were regarded with some degree of skepticism. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution and determining the habitat requirements of this taxon. These data required special attention because of the diversity of persons and methods used in their collection. When information presented in this assessment is based on personal communications with a specialist, those sources are cited as "personal communication." While herbarium specimens were used in this assessment, these data were viewed with caution; in some herbaria, 20 percent or more of the specimens are incorrectly identified (Snow personal communication 2002). Independent verification of the identity of herbarium specimens was beyond the scope of this assessment.

Treatment of Uncertainty

Science is a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with

uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964).

However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist, T. C. Chamberlain (1897) suggested an alternative approach to science, where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, or logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide our understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and are used in synthesis for this assessment. The scarcity of ecological, biological, and natural history information on *Ipomopsis spicata* ssp. *robruthiorum* limits the ability to formulate specific conclusions relative to conservation and management. Because of the scarcity of information on this taxon, information from other *Ipomopsis* species within and outside the region was used in preparing this assessment. It is clearly noted in this document when inferences based on available knowledge have been used to inform our understanding of *I. spicata* ssp. *robruthiorum* in Region 2.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will follow guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, an independent scientific organization. This assessment was reviewed by at least two recognized experts on this taxon or related taxa. Peer review was intended to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

In 1993, the United States Fish and Wildlife Service nominated *Ipomopsis spicata* ssp. *robruthiorum* as a candidate for listing as threatened or endangered, Category 2 under the Endangered Species Act. Taxa included in Category 2 were those for which current information indicated that proposing to list as endangered or threatened was possible, but appropriate or substantial biological information was not on file to support an immediate rule-making. The Category 2 list was discontinued in 1995, so this taxon no longer has Category 2 list status under the Endangered Species Act (**Table 1**; Heidel personal communication 2004).

From 1993 to 2003, the USFS Region 2 designated *Ipomopsis spicata* ssp. *robruthiorum* a sensitive species because of a significant current or predicted downward trend in population numbers, density, or habitat capability (USFS 1995). In 2003, the Rocky Mountain Region revised the Regional Forester's sensitive species list based on evaluations of species with potential viability concerns. As a result, *I. spicata* ssp. *robruthiorum* was not included on the updated sensitive species list. Because it is rare and threats appear to be low, the taxon was recommended for consideration for other USFS emphasis species lists at the forest level, such as species of local concern (Warren et al. 2003).

The global distribution of this taxon lies completely within the Shoshone National Forest; therefore, the Bureau of Land Management, the National Park Service, and tribes within Wyoming give no official status to *Ipomopsis spicata* ssp. *robruthiorum* (Fertig et al. 1994, Heidel personal communication 2004).

Table 1. Management status of *Ipomopsis spicata* ssp. *robruthiorum*.

Listing	Rank
USDA Forest Service, Region 2, Sensitive Species List	Not listed
USDI Fish and Wildlife Service, Endangered Species Act	Not listed
USDI Bureau of Land Management	Not listed
USDI National Park Service	Not listed
Indian Tribes within Wyoming	Not listed
NatureServe global rank[1]	G5T2
Wyoming Natural Diversity Database (for *Ipomopsis spicata* ssp. *robruthii*)	S2
Colorado, Kansas, Nebraska, South Dakota natural heritage programs	Not listed, not known in state

[1]Key to rankings: G = Global rank based on range-wide status, S = State rank based on status of a species in an individual state, T = Trinomial rank used for subspecies or varieties, based on range-wide status.
G1, T1 or S1 Critically imperiled globally or statewide because of rarity (5 or fewer occurrences in its range/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G2, T2 or S2 Imperiled globally or statewide because of rarity (6-20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G3, T3 or S3 Vulnerable throughout its range or locally restricted (21-100 occurrences).
G4, T4 or S4 Apparently secure globally or statewide, though it might be quite rare in parts of its range, especially at the periphery.
G5, T5 or S5 Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

The global status rank G5T2 assigned by NatureServe indicates the relative rarity or endangerment of the taxon worldwide (**Table 1**; NatureServe 2004). The NatureServe global rank, G5, means that the species, *Ipomopsis spicata*, is globally secure; the T2 rank means that the subspecies, *I. spicata* ssp. *robruthiorum*, is imperiled due to its rarity (Fertig et al. 1994, Fertig 2000).

The Wyoming Natural Diversity Database (Wyoming Natural Diversity Database) lists *Ipomopsis spicata* ssp. *robruthii* (synonym for *I. spicata* ssp. *robruthiorum*) as endemic to Wyoming, gives it a conservation priority level of medium, and ranks the taxon as S2, meaning that it is imperiled in the state because of rarity or vulnerability to extirpation. This taxon is not known to exist in the other states within USFS Region 2 (i.e., Colorado, Kansas, Nebraska, South Dakota), and it is not currently listed or ranked in those states.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Ipomopsis spicata ssp. *robruthiorum* is endemic to the Absaroka Mountain Range of Park and Hot Springs counties in northwestern Wyoming. All known occurrences are on lands managed by the Shoshone National Forest and administered by the Clarks Fork, Greybull, and Wapiti ranger districts (Fertig 1995, Wyoming Natural Diversity Database 2002). The taxon is not designated a USFS Region 2 sensitive species (USDA Forest Service 2003).

There are currently no federal regulatory mechanisms or conservation strategies for *Ipomopsis spicata* ssp. *robruthiorum*, and USFS Region 2 has no management plans that specifically address its conservation. Occurrences of this taxon within the Washakie and North Absaroka wilderness areas are provided protection from motorized vehicles but are not necessarily protected from other threats. Wilderness status ensures that the area is protected and managed to preserve its natural conditions (Wilderness Act - 16 U.S.C. 1 1 21); however, because wilderness area regulations do not include specific protections for *I. spicata* ssp. *robruthiorum*, protection is not guaranteed. The occurrence within the proposed Grizzly Creek Research Natural Area (RNA) could receive a higher level of protection with such designation. The primary objective of an RNA is to "...preserve a wide spectrum of pristine representative areas that typify important forest, shrubland, grassland, alpine, aquatic, geologic, and similar natural situations" (Jones and Fertig 1999). One of the specific objectives of the proposed Grizzly Creek RNA is to protect elements of biological diversity. Therefore, designating Grizzly Creek as an RNA implies that *I. spicata* ssp. *robruthiorum* would receive a higher level of protection, but does not guarantee it.

Ipomopsis spicata ssp. *robruthiorum* is not currently designated a USFS Region 2 sensitive species (USDA Forest Service 2003). From 1993 to

2003, however, the taxon was designated sensitive by USFS Region 2 and was provided some protection under various management and conservation strategies designed to protect plant species on federal lands. Management and conservation actions taken by the USFS included surveying for the taxon's presence and/or checking the taxon's distribution maps for its presence before management activities could occur. *Ipomopsis spicata* ssp. *robruthiorum* has not been included in any National Environmental Policy Act products (i.e., environmental assessments, environmental impact statements) because no projects have been conducted in its known occurrence area, and the taxon has not been encountered during projects within its potential habitat (Houston personal communication 2004, Sharp personal communication 2004). In instances where *I. spicata* ssp. *robruthiorum* was found in a proposed project area (i.e., areas proposed for trail construction), the activity was designed to avoid the occurrence area (Houston personal communication 2003). Since the loss of its sensitive status designation, no current management and conservation strategies have been provided for the taxon.

The Wyoming Natural Diversity Database classifies this taxon as S2, imperiled in the state, because of rarity (6 to 20 occurrences), or because of other factors that make it very vulnerable to extinction throughout its range. Designation by the Wyoming Natural Diversity Database draws attention to taxa in need of protection through conservation strategies. However, a heritage program designation does not provide legal protection.

Existing regulatory mechanisms, management plans, and conservation strategies are inadequate to ensure current and future protection of *Ipomopsis spicata* ssp. *robruthiorum*. No federal regulatory mechanisms or conservation strategies have been established for the protection of *I. spicata* ssp. *robruthiorum*. Occurrences within wilderness areas are protected from motorized vehicles but are still potentially threatened by invasive species. Specific regulation of management activities near a known occurrence is not provided at present. Even if such regulation were provided, the lack of information on *I. spicata* ssp. *robruthiorum*'s biology, community ecology, and response to management activities would make it difficult to identify appropriate conservation measures for the taxon. While avoiding the taxon during management activities may have averted direct impacts in the past, such actions are not enough to ensure the taxon's survival, and may or may not have been beneficial. More information on the taxon's population size and trend, biology, community ecology, and response to management is needed to develop adequate regulatory mechanisms and management plans and to ensure future conservation of this taxon.

Biology and Ecology

Systematics and description

Systematics and synonymy

Ipomopsis belongs to the Solanales Order of the Magnoliopsida (Dicotyledon) Class of vascular flowering plants. The genus *Ipomopsis* is a member of the Polemoniaceae (phlox) family (USDA Natural Resources Conservation Service 2002). There are currently seven species of *Ipomopsis* in Wyoming (Dorn 2001). *Ipomopsis spicata* is a perennial plant with alternate leaves, a corolla not over 10 mm long, and filaments shorter than the anthers. Within *I. spicata*, there are two varieties and one subspecies recognized in Wyoming. These include *I. spicata* var. *spicata* (Nutt.) Grant, *I. spicata* var. *orchidacea* (Brand) Dorn, and *I. spicata* ssp. *robruthiorum* Wilken & Hartman (Dorn 2001). The subspecies, *I. spicata* ssp. *robruthiorum*, is an accepted taxon and is distinguished from the two varieties by differences in the inflorescence shape, corolla lobe length, leaves, and habitat (**Table 2**). For example, simple to divided leaves can be found in *I. spicata* var. *spicata* and *I. spicata* var. *orchidacea*, but not in *I. spicata* ssp. *robruthiorum* (Wilken and Hartman 1991). Occurrences of the two varieties and the subspecies are found in geographic proximity but do not show polymorphic variation consistent with local hybridization between subspecies. Of the three subspecific taxa in Wyoming, *I. spicata* ssp. *robruthiorum* has the narrowest geographic distribution, occurring only in northwestern Wyoming. In contrast, *I. spicata* var. *spicata* occurs in eight western states, and *I. spicata* var. *orchidacea* occurs in Wyoming, Montana, and Idaho (Wilken and Hartman 1991).

The genus *Ipomopsis* was first applied in 1803 by Michaux (Grant 1956) to a species that grows in the southeastern United States. Subsequently, various authors placed a number of species from the western United States in the genus. Over time, different taxonomic treatments resulted in the transfers of species to and from the genus *Ipomopsis* and the genera *Phlox*, *Cantua*, *Loeselia*, and *Gilia*, and in a long history of disagreements among botanists about the placement of various species in the genus *Ipomopsis* (Grant 1956, Porter 1997, Porter and Johnson 2000). The discovery of cytological resemblances between *I. aggregata* and *G. aggregata* led to a search for morphological

Table 2. Diagnostic characteristics of the three subspecific taxa of *Ipomopsis spicata* in Wyoming.

Ipomopsis spicata	Inflorescence	Height	Corolla lobe	Leaves	Habitat
ssp. *robruthiorum*	subcapitate, ≥ 50 percent height	plants 2 to 7 cm, internodes obscure	2 to 4 mm	divided twice in part, primary divisions ≥ 7	alpine and subalpine
var. *spicata*	elongated, 50 to 80 percent height	plants 6 to 23 cm	2 to 3 mm	simple (no divisions) to divisions ≤ 4 to 7 segments	plains, hills, and slopes
var. *orchidacea*	subcapitate, ≤ 50 percent height	plants 5 to 28 cm, internodes evident	3 to 5 mm	simple to divided once in part, primary divisions ≤ 5 times	ridges and slopes in mountains

Source: Dorn 2001

similarities between these two forms and to the discovery of a number of common characteristics. A reinvestigation of several species within other genera in the Polemoniaceae indicated that their affinities also were with the *Ipomopsis* alliance. This investigation resulted in an amplified concept of the *Ipomopsis* genus (Porter 1997, Porter and Johnson 2000). *Ipomopsis spicata* was first described as *G. spicata* in 1848 (Constance and Rollins 1936, Grant 1956).

Ipomopsis spicata ranges from the high western plains to alpine and subalpine habitats in the Rocky Mountain region. Climatic and topographic changes that occurred in the Rocky Mountain region during the Miocene, Pliocene, and Pleistocene periods probably led to geographic isolation, differentiation, and the independent evolution of local races (Rosenthal 1999). Wilken and Hartman (1991) systematically reassessed the genus to present a taxonomic treatment that accounts for major patterns in variation. After measuring 45 characteristics from 900 herbarium specimens representing the full extent of *I. spicata*'s geographical and ecological range, Wilken and Hartman (1991) assigned subspecific status to five principal geographic taxa. These taxa were mostly allopatric and differed from each other in several floral and vegetative characteristics (Wilken and Hartman 1991). The five taxa were ssp. *spicata*, ssp. *capitata*, ssp. *orchidacea*, ssp. *tridactyla*, and ssp. *robruthiorum*.

The Natural Resources Conservation Service PLANTS Database (USDA Natural Resources Conservation Service 2000), which is the corporate standard for the USFS, recognizes *Ipomopsis spicata* ssp. *robruthiorum* as the scientific name for this taxon. Consequently, this is the name chosen for use in this assessment. *Ipomopsis spicata* ssp. *robruthiorum* is also known as *I. spicata* ssp. *robruthii* and Kirkpatrick's ipomopsis. It was originally named *I. spicata* ssp. *robruthii* in honor of Rob and Ruth Kirkpatrick (Kirkpatrick 1987, Welp et al. 2000). The subspecific epithet '*robruthii*' was recommended by R. Barneby as a way to represent two people but only one couple (Hartman and Nelson 1998). *Robruthii* is the spelling accepted by the Wyoming Heritage Program (the spelling *robruthiae* has been used elsewhere) and is more widely used than the epithet *robruthiorum*. Depending on the reference, *robruthii* is either referred to as a variety or subspecies. The change from subspecies to variety is the result of work by Robert Dorn, who renamed many subspecies to varieties (Scott personal communication 2002). Dorn (1992) also proposed the name *robruthiorum* due to his interpretation that the epithet *robruthii* was technically incorrect. Ron Hartman has since shown that *robruthii* is valid under the International Code of Botanical Nomenclature (St. Louis Code 2000) because it is made up of two names (combining the names Rob and Ruth Kirkpatrick) (Heidel personal communication 2004). Although the suffix -orum has been used to indicate the plural, the derivative 'robruth' is technically fictitious, and thus the suffix -ii is acceptable and correct (Welp et al. 2000). Therefore, *I. spicata* ssp. *robruthii* is the correct taxonomic name for this taxon (Stearn 1992).

Non-technical description

Ipomopsis spicata ssp. *robruthiorum* is a densely leafy, perennial herb that usually has a single vegetative rosette and a tap root (**Figure 1**). Plants are often found in clusters of six to 10 stems (Wyoming Natural Diversity Database 2002). Flowering stems are 1 to 8 cm long and arise from a basal leaf rosette. Basal leaves are 1 to 7 cm long, and stem leaves are 0.5 to 3 cm long. The basal and stem leaves are divided into two to six lateral leaflets, each with four to eight narrow

(A)

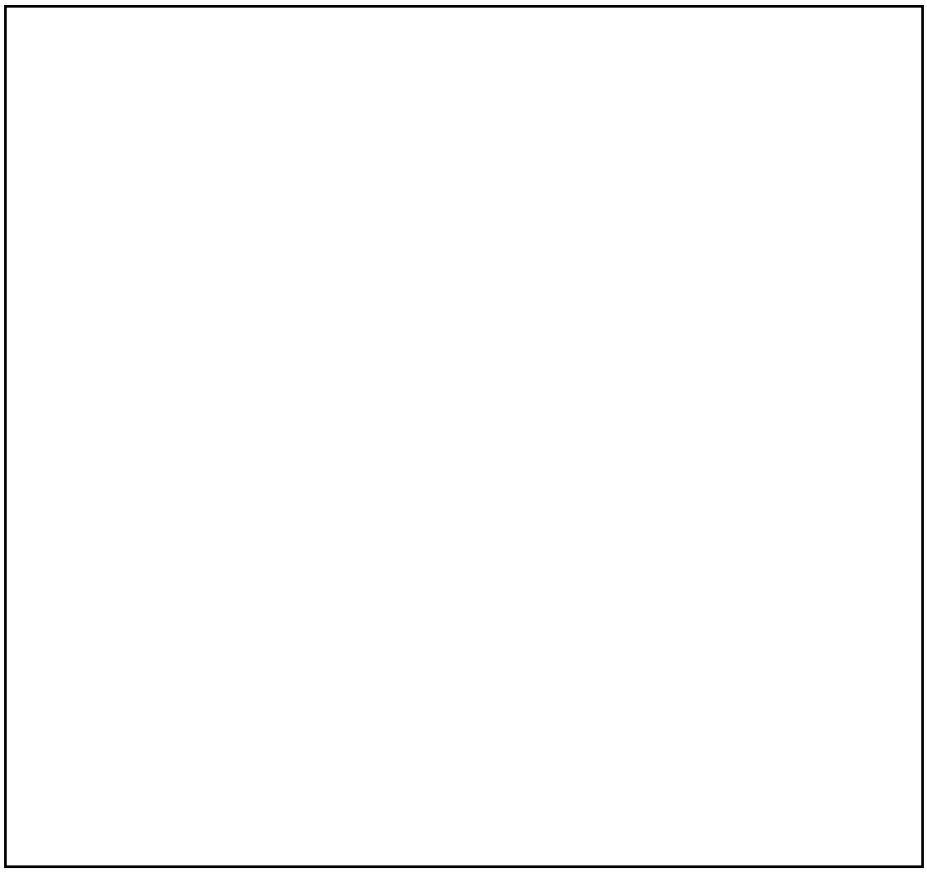
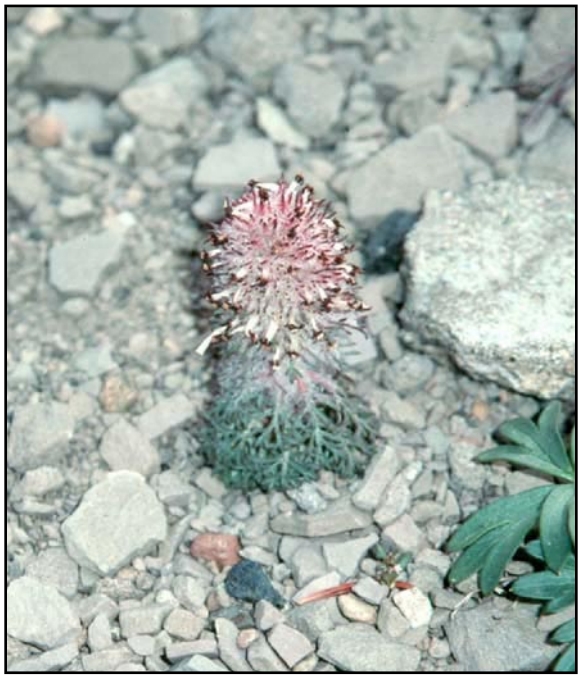


Illustration of *Ipomopsis spicata* ssp. *robruthiorum* by Tracey Wager, used with permission.

(B)



Photograph of *Ipomopsis spicata* ssp. *robruthiorum* by Walt Fertig, used with permission.

Figure 1. Illustration and photograph of *Ipomopsis spicata* ssp. *robruthiorum*.

segments, and are covered with dense woolly hairs. The inflorescence (1.5 to 4 cm long) is at the terminal end of the stem, and can be dense to elongate. It is composed of numerous, densely aggregated flowers. Flowers bloom and fruit in July to August and are white, bluish, or yellow in color. Flowers are 5-lobed, tubular, and clustered into the woolly inflorescence. After senescence, the flower is brown. One to three, tan to gray-colored seeds are produced per flower, in a 3 to 5 mm long capsule (Wilken and Hartman 1991, Dorn 1992, Fertig et al. 1994, Dorn 2001).

References to technical descriptions, photographs, line drawings

Technical descriptions of *Ipomopsis spicata* ssp. *robruthiorum* are in Grant (1956), Wilken and Hartman (1991), Fertig et al. (1994), and Dorn (2001). Photographs and line drawings are found in Wilken and Hartman (1991), Fertig et al. (1994), Fertig (2000). A photograph and a line drawing of the taxon are provided in **Figure 1**.

Distribution and abundance

Ipomopsis spicata ssp. *robruthiorum* occurs in Park and Hot Springs counties in Wyoming, within Region 2 of the USFS (**Figure 2**; Rocky Mountain Herbarium 2002). It occurs on volcanic soils and substrates in the Absaroka Mountains from 6,650 to 13,140 feet (2,210 to 4,380 m) in elevation (Handley et al. 2002). The taxon's total known range encompasses approximately 750 square miles (1,200 square km). All 16 known occurrences of *I. spicata* ssp. *robruthiorum* occur on lands managed by the Shoshone National Forest and administered by the Clarks Fork, Greybull, and Wapiti ranger districts (**Table 3**, **Figure 3**; Fertig 1995). General locations for the taxon are as follows: northern side of Ptarmigan Mountain, Clayton Mountain, near Trout Peak, northwestern side of Windy Mountain, Piney Creek drainage, Francs Peak, Chief Mountain ridge, Gear Point, the ridge northwest of Gear Point, Stinking Water Peak, Cougar Creek drainage, the ridge north of Monument Mountain, ridges north and south of Sleeping Giant Mountain, near Clayton Mountain, Carter Mountain, and Moss Creek drainage. It is likely that *I. spicata* ssp. *robruthiorum* also occurs on private lands with suitable habitat that are adjacent to National Forest System lands.

Occurrence[1] data have been compiled for this assessment from WYNDD, the Rocky Mountain Herbarium (RM), the Central Wyoming College Herbarium, and the University of Northern Colorado Herbarium. The most recently located occurrence was in 1997 (Fertig 2000, Handley et al. 2002). Two specimens have been collected from occurrence numbers 1, 9, and 16; only a single specimen has been collected from each of the remaining 13 occurrences (**Table 4**; Wyoming Natural Diversity Database 2002). The WYNDD does not encourage the collecting of more than one specimen from a single occurrence (Heidel personal communication 2004). The RM is the main repository for specimens of this taxon; Wyoming Natural Diversity Database records show that the RM has a voucher specimen for each occurrence (Heidel personal communication 2004). The three duplicate herbarium specimens from occurrence numbers 1, 9, and 16 are housed at other institutions, but the WYNDD does not track which herbaria have duplicate vouchers (**Table 4**; Evert 1981, Hartman 1983, Hartman 1985, Fertig 1997a, Heidel personal communication 2004).

All known occurrences of *Ipomopsis spicata* ssp. *robruthiorum* are located on the Shoshone National Forest (Handley et al. 2002), including six occurrences within the Washakie Wilderness and eight occurrences within the North Absaroka Wilderness, including one occurrence within both the North Absaroka Wilderness and the proposed Grizzly Creek RNA (Fertig 1998). Several portions of the Absaroka Mountains have been systematically surveyed for floristic diversity, including the headwaters of the Yellowstone River (Snow 1989), the southeastern Absaroka Mountains (Kirkpatrick 1987), the North Fork Shoshone River drainage (Evert 1991), the proposed Grizzly Creek RNA (Jones and Fertig 1999), the North and South Fork Shoshone River drainages (Fertig 1997a and Fertig 1998), and Pat O'Hara Mountain (Fertig 1998). Focused surveys have also occurred for target species of concern (Mills and Fertig 1996, Fertig 1997b). For example, the one-and-a-half month survey conducted by Fertig in 1997 surveyed large portions of the Shoshone National Forest for 17 species listed as sensitive. A total of 46 plant species of concern were located, including one occurrence of *I. spicata* ssp. *robruthiorum* (Fertig 1997b). A floristic survey of selected areas within the Shoshone National Forest, including the northern portion of *I. spicata* ssp. *robruthiorum*'s known range, was conducted by

[1]"Occurrence" as used in this document means a group of plants found at a specific location, which may include a single grouping of individuals or several sub-groups in the same area. An occurrence may or may not be equivalent to a biological population (NatureServe 2001).

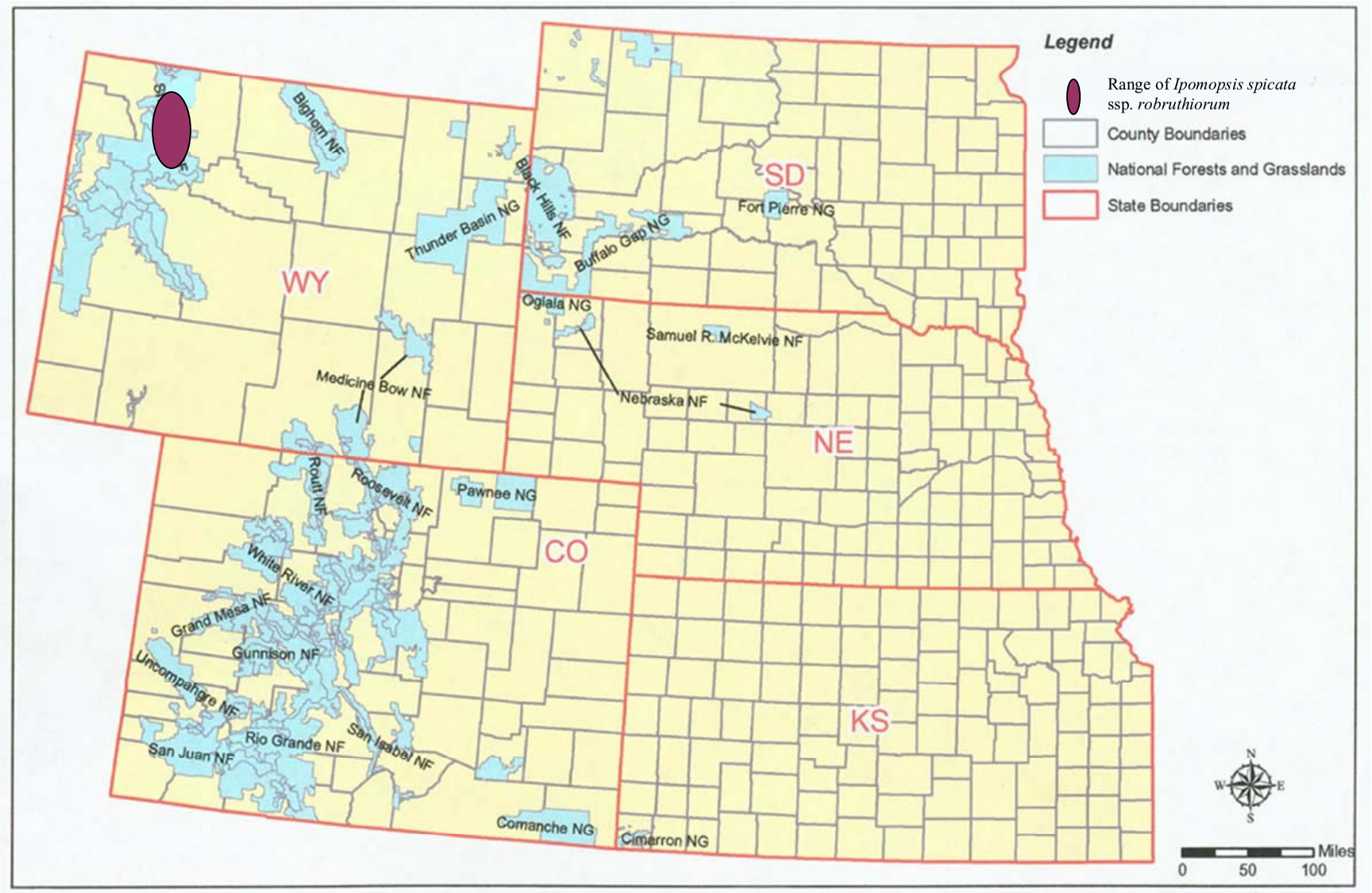


Figure 2. Range of *Ipomopsis spicata* ssp. *robruthiorum* in USDA Forest Service Region 2.

Table 3. Summary of locations and abundance data for *Ipomopsis spicata* ssp. *robruthiorum*. Data is summarized from Wyoming Natural Diversity Database database. The occurrence numbers correspond to the biological and conservation database record code for Wyoming Natural Diversity Database. All occurrences are within Park County, Wyoming, and no occurrence was observed more than twice.

Arbitrary Occurrence No.	USGS Quadrangle	Land Owner and Land Designation	Location	Abundance	Date First / Last Observed	Specimen
1	Flag Peak	Shoshone National Forest, Washakie Wilderness	Absaroka Range, North Fork Shoshone River drainage, northern ridge of Ptarmigan Mountain on divide between Cougar and Pagoda Creeks, ca 3.9 miles east of Elk Fork Creek, ca 5 miles south of US Highway 14, 16 & 20.	Total 500 to 650 plants; clusters of 6 to 10 plants	1981 / 1996	E. Evert *3627*, W. Fertig *16972*
2	Clayton Mountain	Shoshone National Forest, Washakie Wilderness	Absaroka Range, North Fork Shoshone River drainage, Clayton Mountain, ca 3 to 4 miles south of US Highway 14, 16 & 20.	No notes	1982 / 1982	E. Evert *4363*
3	Sunlight Peak	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, North Fork Shoshone River drainage, Monument Mountain, ca 5 miles north of US Highway 14, 16 & 20.	No notes	1982 / 1982	E. Evert *4553*
4	Dead Indian Peak	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, 1 air mile east of summit of Trout Peak.	No notes	1985 / 1985	R. Hartman *22433*
5	Geers Point	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, Geers Point and ridge to northwest and then east, 8 to 9 air miles west-southwest to west of Sunlight Ranger Station.	No notes	1985 / 1985	R. Hartman and B. Nelson *22187*
6	Windy Mountain	Shoshone National Forest	Absaroka Range, summit and upper northwest slope of Windy Mountain, 6 to 7 air miles north-northwest of Sunlight Ranger Station.	No notes	1985 / 1985	R. Hartman and B. Nelson *21823*
7	Aldrich Basin	Shoshone National Forest, Washakie Wilderness	Southeast Absaroka Range, Carter Mountain, ca 28 air miles west of Meeteetse, ca 1.5 miles northwest of Piney Pass in the vicinity of the Carter Triangulation Station.	No notes	1983 / 1983	R. Kirkpatrick *2610*
8	Francs Peak	Shoshone National Forest	Absaroka Range, Chief Mountain to Galena Ridge, ca 2.5 to 3 air miles north of Kirwin.	No notes	1984 / 1984	R. Hartman *19291 a*
9	Sunlight Peak, Stinking Water Peak	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, vicinity of Sunlight Peak, two locations: (1) near the head of Sunlight Creek, Stinking Water Mountain and Sunlight Peak; (2) "saddle immediately east of Stinkingwater Peak then east to summit of Peak 11127".	No notes	1965 / 1996	R. Hartman *55877*; R. Scott *647*
10	Clayton Mountain	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, ridge/divide between Moss Creek and Clearwater Creek ca 1.5 to 2.5 miles north of US Highway 14, 16 & 20.	No notes	1989 / 1989	E. Evert *17600*
11	Sunlight Peak	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, North Fork Shoshone River drainage, northwest side of Sleeping Giant Mountain at head of Mormon Creek.	No notes	1981 / 1981	E. Evert *3349*

Table 3 (concluded).

Arbitrary Occurrence No.	USGS Quadrangle	Land Owner and Land Designation	Location	Abundance	Date First / Last Observed	Specimen
12	Sunlight Peak	Shoshone National Forest, North Absaroka Wilderness	Absaroka Range, west of Libby Creek on south slope of Sleeping Giant Mountain.	No notes	1984 / 1984	E. Evert *3349*
13	Francs Peak	Shoshone National Forest, Washakie Wilderness	Absaroka Range, Franc's Peak.	No notes	1983 / 1983	R. Hartman and R. Kirkpatrick *16767*
14	Ptarmigan Mountain	Shoshone National Forest, Washakie Wilderness	Absaroka Range, South Fork Shoshone River Drainage, southeast flank of Wapiti Ridge, upper base of Citadel Mountain up rocky east end and along alpine ridge west to summit.	No notes	1996 / 1996	R. Hartman *55311*
15	Valley	Shoshone National Forest, Washakie Wilderness	Absaroka Range, Ishawooa Mesa trail, ca 28 air miles southwest of Cody, ca 1.5 air miles south of Ishawooa Creek.	No notes	1997 / 1997	D. Rosenthal *2536*
16	Dead Indian Peak, Flag Peak	Shoshone National Forest, North Absaroka Wilderness; proposed Grizzly Creek Research Natural Area	Absaroka Range, North Fork Shoshone River Drainage, north-south trending ridge along the divide between Sweetwater Creek and Horse Creek. ca 2 air miles north of Wapiti Campground and the North Fork Shoshone River.	5 to 9 plants/m^2; total 50 to 100 plants	1997 / 1997	W. Fertig *17606*, *17983*

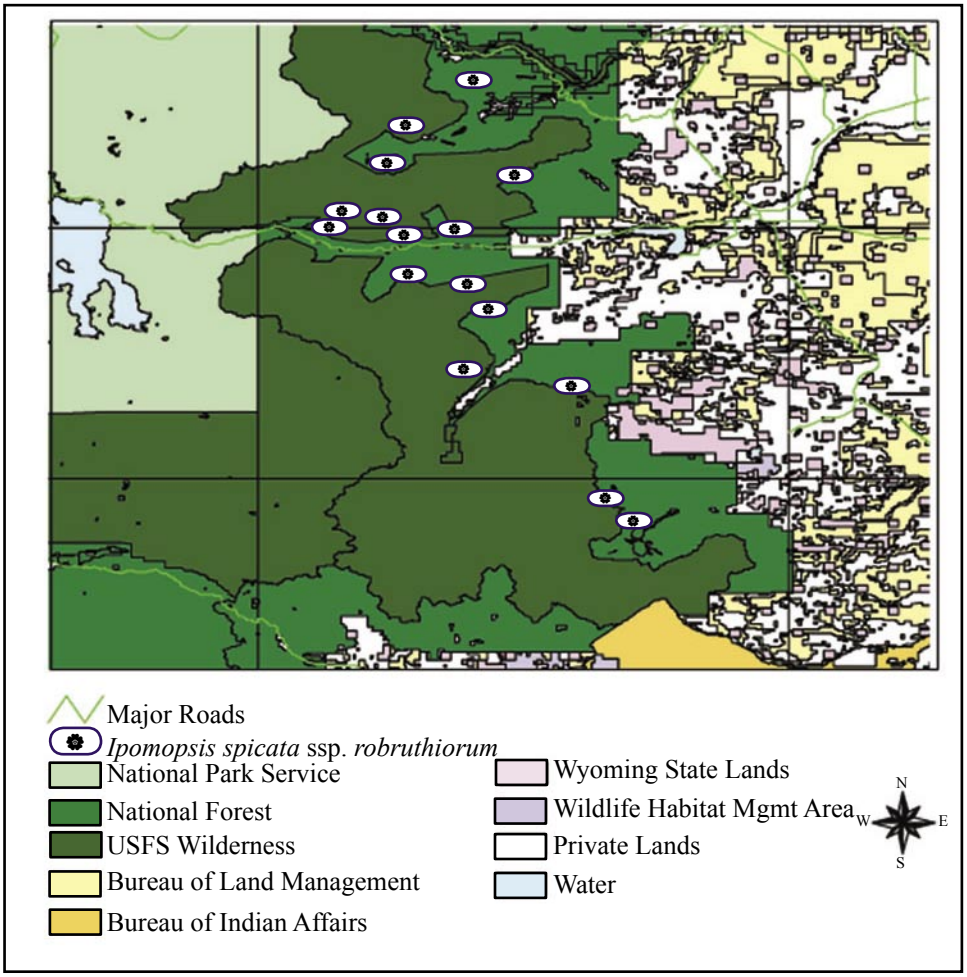


Figure 3. *Ipomopsis spicata* ssp. *robruthiorum* occurrences in northwestern Wyoming in relation to land ownership.

Table 4. *Ipomopsis spicata* ssp. *robruthiorum* habitat by occurrence. Data is summarized from Wyoming Natural Diversity Database and herbarium specimen labels. The occurrence numbers correspond to the biological and conservation database record code for Wyoming Natural Diversity Database. "No notes" indicates no data is available for the occurrence. Additional habitat information in the text, derived from herbarium specimens and USDA Forest Service reports, could not be matched to a specific occurrence.

Arbitrary Occurrence No.	USGS Quadrangle	Elevation (ft.)	Habitat
1	Flag Peak	10,200	Semi-bare eroded slopes of light brownish-white clay-gravel andesite volcanic soil. Cushion plant/low forb community with average vegetative cover of 40 percent (but as low as 10 percent in some sites). Occurs with *Townsendia condensata* var. *anomala*, *Artemisia michauxiana*, and *Penstemon absarokensis*.
2	Clayton Mountain	No notes	Tundra.
3	Sunlight Peak	No notes	Tundra.
4	Dead Indian Peak	11,800 to 12,048	Rocky slopes.
5	Geers Point	No notes	Alpine meadows and rocky slopes.
6	Windy Mountain	9,600 to 10,200	Open subalpine slopes with scattered *Pinus albicaulis*, alpine meadows and rocky slopes.
7	Aldrich Basin	11,000 to 11,400	Alpine meadows and slopes; turf mats and meadows.
8	Francs Peak	11,500 to 12,000	Alpine meadows and talus slopes.
9	Sunlight Peak, Stinking Water Peak	10,400 to 11,127	Steep scree slides, rocky slope and summit.
10	Clayton Mountain	7,600 to 8,300	Open Douglas-fir forest and dry, rocky openings. Occurs with *Townsendia condensata* ssp. *anomala*, *Antennaria flagellaris*, and *Zauschneria garrettii*.
11	Sunlight Peak	9,980	In scree and sand with *Townsendia parryi*, *Castilleja nivea*, *Delphinium bicolor*, and *Trifolium parryi*.
12	Sunlight Peak	No notes	No notes.
13	Francs Peak	12,000 to 13,153	Rocky alpine ridge with scattered turf communities dominated primarily by *Geum rossii* and *Trifolium nanum*.
14	Ptarmigan Mountain	10,800 to 11,896	Rocky slopes and alpine meadow on volcanic soils.
15	Valley	10,000 to 10,300	Alpine meadow and down to treeline. Occurs with *Delphinium* spp., *Draba* spp., and *Townsendia* spp.
16	Dead Indian Peak, Flag Peak	7,300 to 7,500	Observed in: 1) openings among *Pinus flexilis/Juniperus scopulorum* woodlands in cushion plant/bunchgrass communities on southeast-facing semi-barren, southeast-facing slopes of loose andesite clay with scattered rock and sparse gravel; 2) with *Elymus spicatus/ Chrysothamnus nauseosus* community with scattered low forbs and cushion plants on ridgetops of loose, crumbly light-brown andesite clay with over 80 percent cover of bare soil; (3) in low elevation dry wash with loose, gray, fine-textured volcanic soil in opening within *Pseudotsuga menziesii* forest.

Rosenthal (1999). This survey was the most inclusive survey of the taxon's range and included lands bounded by US Hwy 212 and Wyoming Hwy 296 to the north, Wyoming Hwy 120 and the Shoshone National Forest boundary to the east, the South Fork of the Shoshone River to the south, and Yellowstone National Park to the west. The southern portion of the taxon's known range has been less intensively surveyed. While many portions of the Shoshone National Forest have been intensively floristically surveyed, no formal range-wide survey focusing on *I. spicata* ssp. *robruthiorum* has yet been conducted. Given the lack of a focused survey and few collections, there is potential for more occurrences to be located if a focused survey for *I. spicata* ssp. *robruthiorum* is conducted in its known and potential range.

Census data for most *Ipomopsis spicata* ssp. *robruthiorum* occurrences are lacking (Wyoming Natural Diversity Database 2002), and most herbarium specimens do not document the occurrence size (**Table 3**). Overall abundance is not known. Unpublished population records are available for two of the 16 occurrences. These records, collected during one mid-summer site visit, give only a snapshot of abundance. Occurrence size ranges from sparse (1 to a few individuals), small (50 to 75 individuals) to moderate (500 to 650 individuals) (Fertig 1997a, Handley et al. 2002). Additional occurrence records describe *I. spicata* ssp. *robruthiorum* as locally common in favorable microsites with 5 to 9 plants per m^2 and population totals conservatively estimated at 50 to 100 plants (Wyoming Natural Diversity Database 2002). It is not known whether differences in recorded population size from site to site are typical of conditions throughout its geographic distribution. Population sizes are likely to fluctuate annually due to climatic variation.

Plants are often found in clusters of six to 10 stems (Wyoming Natural Diversity Database 2002). Clusters of flowering stems result from the branching of the subterranean caudex (Wilken and Hartman 1991) and may increase reproductive output and/or be an adaptation to the alpine environment (Lambers et al. 1998). Physiological and morphological adaptations decrease adverse effects from wind, cold, and evapotranspiration. Growing in clusters can increase the plant's boundary layers, thus decreasing evaporation, and creating a more favorable, energy-effective microclimate for growth (Lambers et al. 1998).

When a known site on Clayton Mountain was resurveyed in 1996, no individual *Ipomopsis spicata* ssp. *robruthiorum* plants were located (Fertig 1997b). This 1996 resurvey record does not include an exact location, and it is not incorporated into the WYNDD occurrence records; therefore, it is impossible to determine which of the two Clayton Mountain occurrences was revisited. There is a lack of notes from the first visit, so the previous size of the occurrence is unknown. One possible reason that no plants were found during the resurvey is that the plants may only produce aboveground stems in favorable climatic years. If this is the case, then surveys to locate additional occurrences will be most productive if they are conducted during years when weather conditions are favorable for production of aboveground stems. Survey and monitoring work remains a high priority to determine population abundance and stability, and to determine the rarity of this taxon.

Population trend

Long-term monitoring has not been conducted for *Ipomopsis spicata* ssp. *robruthiorum*, and no monitoring studies are planned for the near future. No quantitative data exist in the literature, in status reports, from herbarium specimens, or from WYNDD to determine population trend. Only two *I. spicata* ssp. *robruthiorum* locations have been visited more than once. For most occurrences, whether visited one or two times, surveyors did not document the number of plants (**Table 3**). Therefore, only the presence of plants can be confirmed, not population numbers or population trends. Although trend data are lacking, Fertig (2000), Handley (2000), and Welp (2002) contend that the population is likely stable. There are no data to support or refute this statement on population stability. The potential for a downward trend exists if the climate changes (Fertig 2000, Welp et al. 2000). Initiating long-term population monitoring could assist in detecting population changes.

Habitat

Ipomopsis spicata ssp. *robruthiorum* is endemic to the Absaroka Mountains of northwestern Wyoming, where it is found on soils derived from volcanic parent materials. Mafic to felsic (dark to light) andesites (fine grain volcanic rocks) are found throughout the mountains. Most of *I. spicata* ssp. *robruthiorum*'s known range is covered by the Sunlight Group of dark-colored andesitic lava flows and volcanic rock (Rosenthal 1999). In the alpine zone, the semi-bare, eroded slopes where these plants live are light brownish-white andesite gravel, fine andesite soils, or clay-rich gravelly substrates derived from andesite (Fertig 1995, Fertig 1997b, Welp et al. 2000). Annual

average precipitation in the region is 16 inches (35 cm) at lower elevations and 24 inches (53 cm) or more at higher elevations. The majority of the precipitation is winter snow and summer afternoon rain showers. The mean annual temperature in the region is 40 °F (4 °C) (Rosenthal 1999).

The habitat of *Ipomopsis spicata* ssp. *robruthiorum* is discontinuous across the landscape (Handley et al. 2002). *Ipomopsis spicata* ssp. *robruthiorum* grows on volcanic or sandy substrates at 6,650 to 13,140 feet (2,210 to 4,380 m) elevation on the Shoshone National Forest (Fertig 2000, Welp et al. 2000). Average vegetative cover of a community with *I. spicata* ssp. *robruthiorum* is 40 percent but can be as low as 5 percent (Fertig 1997a). No information exists on the average slope conditions on which these plants grow.

Herbarium and WYNDD records indicate that *Ipomopsis spicata* ssp. *robruthiorum* is found in a wide variety of vegetation types including alpine, subalpine, and montane forests, alpine meadows, tundra, talus or scree slopes, bunchgrass communities, and cushion plant communities (**Table 4**). Forests where the taxon is found include open *Pseudotsuga menziesii* (Douglas-fir) communities, among scattered *Pinus albicaulis* (whitebark pine) trees, and in openings among *Pinus flexilis*/*Juniperus scopulorum* (limber pine/Rocky Mountain juniper) woodlands (Hartman 1985, Welp et al. 2000, Wyoming Natural Diversity Database 2002). In alpine meadows, tundra, bunchgrass communities, and cushion plant communities, *I. spicata* ssp. *robruthiorum* typically grows with other vascular plants adapted to high elevation, dry, rocky sites. Associated herbaceous species include *Townsendia condensata* var. *anomala* (cushion townsend daisy), *Antennaria flagellaris* (pussy-toes), *Zauschneria garrettii* (willow herb), *Delphinium bicolor* (larkspur), *Draba* spp. (whitlow grass), *Stephanomeria runcinata* (skeletonweed), *Artemisia michauxiana* (sagebrush), *Elymus spicatus* (bluebunch wheatgrass), *Penstemon absarokensis* (beardtongue), *Castilleja nivea* (Indian paintbrush), *Lomatium attenuatum* (biscuitroot), *T. parryi* (daisy), and *Trifolium parryi* (clover) (Evert 1981, Fertig 1996, Mills and Fertig 1996, Wyoming Natural Diversity Database 2002). On exposed alpine ridges of scattered turf communities, *I. spicata* ssp. *robruthiorum* grows in communities dominated primarily by *Geum rossii* (avens) and *T. nanum* (clover) (Hartman 1983).

Ipomopsis spicata ssp. *robruthiorum* is most typically found on southeastern aspects of high elevation rocky slopes, but it has also been found in lower elevation dry tributary washes (Nelson 1983, Fertig 1997a). These lower elevation occurrences are probably derived from seeds washed downstream or downslope (Jones and Fertig 1999). Plant associations along washes and streams where *I. spicata* ssp. *robruthiorum* has been found include: *Picea-Abies* (spruce-fir) forests with *Pinus contorta* (lodgepole pine), *P. flexilis*, open *Artemisia* (sagebrush) grasslands, and stands of *Populus tremuloides* (quaking aspen) and *Populus* spp. (cottonwoods). On banks of dry washes in openings with *Pseudotsuga menziesii*, *Juniperus scopulorum*, *Elymus spicatus* (wildrye), *Chrysothamnus nauseosus* (rubber rabbitbrush), and *Pinus flexilis*, *I. spicata* ssp. *robruthiorum* grows with patches of *Melilotus officinalis* (yellow sweetclover), *Solidago* spp. (goldenrod), *Aster* spp. (aster), and *Leucopoa kingii* (western grass) (Fertig 1997a).

Given the wide range of habitats of *Ipomopsis spicata* ssp. *robruthiorum*, it is possible that more occurrences of this endemic taxon exist in the region. Determining whether more occurrences do exist will be necessary to determine appropriate management and conservation activities.

Reproductive biology and autecology

Ipomopsis spicata ssp. *robruthiorum* is a perennial plant occurring at high elevations. As with many species of *Gilia* and *Ipomopsis*, the taxon is found on moderately disturbed sites (Fertig 1995). Disturbances typical of these sites include wind erosion and snow loading, which may prevent other species from colonizing the high elevation sites. Although *I. spicata* ssp. *robruthiorum*'s life history or plant strategies have never been studied, some of its characteristics are those of a K-selected species. Characteristics of a K-selected species can include high resistance to disturbance, more energy invested in survivorship than reproduction, and/or large seed size. Through selection pressures, this taxon has evolved characteristics that enable it to persist in stressful habitats. Some K-selected species have a high resistance to stress and perturbations, but once perturbed, they have little capacity to recover (Begon et al. 1990). If this applies to *I. spicata* ssp. *robruthiorum*, it suggests that this taxon can tolerate low levels or short durations of stress, but it may not be able to tolerate high levels or prolonged or constant periods of stress. Anderson (1988, 2004) found that *I. polyantha* can colonize and survive in sites that are newly disturbed, or infrequently disturbed, but it does not tolerate prolonged or constant disturbances.

On the Competitive/Stress-Tolerant/Ruderal (CSR) plant strategy theory triangle (Grime 1979), *Ipomopsis spicata* ssp. *robruthiorum* is most representative of a S-R (Stress-Tolerant/Ruderal) species because it tolerates environmental stresses, such as exposure to high winds, direct sun, temperature extremes, wind and soil erosion, and low nutrient substrates. Without additional data about *I. spicata* ssp. *robruthiorum*'s responses to varying types, intensities, and durations of disturbances, the ecological relationships of this taxon will remain speculative.

Disturbance factors

Disturbance may be important for *Ipomopsis spicata* ssp. *robruthiorum*'s survival. Some species of *Ipomopsis* evolved with disturbance such as fire to maintain their habitats or to increase their aboveground biomass (Paige 1992, Collins 1995). For example, *I. aggregata* forms clonal rosettes after fire (Paige 1992). However, whether the disturbance is beneficial or detrimental to the plant's survival may depend on the intensity, duration, and type of disturbance and the size of the occurrence. For example, Heschel and Paige (1995) found that small populations of *I. aggregata* were more susceptible to an experimentally imposed grazing stress than were large populations. Data on the effects of disturbance on *I. spicata* ssp. *robruthiorum* are unavailable.

Reproductive biology

Little is known about the reproductive biology of *Ipomopsis spicata* ssp. *robruthiorum* due to a lack of observations in greenhouse studies and in the field. The primary mode of reproduction is by seed. Vegetative rhizomes or stolons have not been observed for the taxon. Clusters of flowering stems result from the branching of the subterranean caudex (Wilken and Hartman 1991) and may increase reproductive output. The month during which seeds germinate is unknown. Plants flower and fruit from July to August and finish their life cycle in August to September. While it is typical for species of *Ipomopsis* to be monocarpic, no specific information is available about monocarpy in *I. spicata* ssp. *robruthiorum* (Anderson 1988, 2004). Plants of *I. spicata* var. *spicata* and *I. spicata* var. *orchidacea* are monocarpic; they live for several years, flower once, and then die. In plants of these two taxa with multiple rosettes, vegetative rosettes may continue to live after the reproductive rosette dies and may eventually flower itself. However, this is not considered to be a form of vegetative reproduction because these offshoots remain a part of the parent plant and do not survive beyond flowering (Wilken personal communication 2004). This also takes place in other members of the genus *Ipomopsis*, including the *I. aggregata* complex (Wilken 1996).

Pollination biology

The pollination biology of *Ipomopsis spicata* ssp. *robruthiorum* has not been studied or observed, so the pollination system and pollinators of *I. spicata* ssp. *robruthiorum* are unknown. All members of the genus *Ipomopsis* have perfect flowers, but species differ in their ability to self- or cross-pollinate (Grant 1956). Some rare *Ipomopsis* species exhibit both self-compatible and outcrossing behaviors (Collins 1995). Potential pollinators of *I. spicata* ssp. *robruthiorum* include moths and hawk-moths (Elam 1983), or the plants may be pollinated by nectar-feeding flies and small pollen-collecting halictid bees, as in *I. spicata* (Grant and Grant 1965). The shallow corolla tubes of *I. spicata* ssp. *robruthiorum* suggest that it is a pollination generalist like *I. polyantha*, which also has shallow corolla tubes. *Ipomopsis* species with large corolla tubes, such as *I. aggregata*, are specialized for hummingbird pollination (Grant and Grant 1965), although in some areas they are also pollinated by hawk-moths (Carpenter 1979). Like most light-colored (white, bluish or yellow) flowers, *I. spicata* ssp. *robruthiorum* is probably pollinated at night (Klein 2004 personal communication).

Seed biology

The seed biology of *Ipomopsis spicata* ssp. *robruthiorum* has not been studied. Studies from related taxa provide models for research. For example, Heschel and Paige (1995) found that in *I. aggregata* seed size and germination success depended on the size of the population. Although the analysis of their work is controversial (Ouborg and Van Groenendael 1995), Heschel and Paige (1995) also suggested that small populations of *I. aggregata* had reduced seed fitness as a result of inbreeding depression. Seeds of *I. spicata* ssp. *robruthiorum*, like other members of the Polemoniaceae, may stay dormant in the soil for extended periods of time to increase the likelihood of germinating under favorable conditions (Baskin and Baskin 2001). Carpenter and colleagues (1993) found that temperature and seed moisture governed germination of *Phlox drummondii*. This is an important characteristic for survival in an environment where conditions vary widely. Maschinski (1996) found that *I. sancti-spiritus* had the highest germination rates when exposed to prolonged cold treatments. Requirements for stratification and scarification of *I. spicata* ssp.

robruthiorum's seeds are likely, given the climatic conditions of the habitat and its rocky substrate.

Although details of its seed biology are unknown, the location of *Ipomopsis spicata* ssp. *robruthiorum* in washes (Jones and Fertig 1999) suggests that the seeds may fall and germinate on the substrate surface, and that the seeds may be dispersed by high winds and spring run-off. These plants may also depend on animals, particularly birds, for long-distance dispersal. The seeds of some members of the Polemoniaceae are coated with a mucilaginous substance, and this may aid the dispersal of seeds on birds' feet (Collins 1995). Whether this mechanism plays a role in the dispersal of *I. spicata* ssp. *robruthiorum* is not known.

Life cycle

The lifespan (age) of *Ipomopsis spicata* ssp. *robruthiorum* has not been studied. However, occurrence records indicate that individuals vary in their lifecycle stage at a given date (Rocky Mountain Herbarium 2002, Wyoming Natural Diversity Database 2002). These individuals may represent juveniles and adults. Low moisture and high stress conditions may preclude flower production. The taxon may flower only in favorable climatic years. Plants may remain in the rosette stage during unfavorable conditions and may produce aboveground biomass only when environmental conditions are favorable. The inability to relocate a known occurrence could be a result of the lack of production of aboveground biomass under unfavorable environmental conditions (Fertig 1997b).

Hybridization

There are no reported instances of hybridization between *Ipomopsis spicata* ssp. *robruthiorum* and other *Ipomopsis* species. However, hybridization with *I. spicata* var. *spicata* and *I. spicata* var. *orchidacea*, which inhabit the same geographic location (Park and Hot Springs counties), is possible (Dorn 2001). Hybridization has been a major evolutionary force in the *Ipomopsis* genus (Grant 1956). The resulting fitness level of the hybrids may depend on which species is the maternal parent. In one case, the hybridization of *I. aggregata* with *I. tenuituba* resulted in an intermediate fitness level of the two parent species (Campbell et al. 1998).

Demography

The chromosome number of *Ipomopsis spicata* is n=7 (Love 1986, Porter 1997). The chromosome number of the subspecies *robruthiorum* is unknown. No studies have examined genetic diversity within *I. spicata* ssp. *robruthiorum*, but isolated or endemic taxa tend to exhibit reduced levels of polymorphism (Karron 1991). Reduced levels of polymorphism can lead to increased vulnerability to disease or extinction. No deductions can be made for *I. spicata* ssp. *robruthiorum* without additional genetic information.

Life history diagram

A life history diagram represents a series of developmental changes undergone by an organism from inception to death. The main demographic components of *Ipomopsis spicata* ssp. *robruthiorum*'s life history diagram include the production of seeds, seedling plants, vegetative plants, and flowering adults (**Figure 4**). The life history diagram of *I. spicata* ssp. *robruthiorum* is typical for a perennial plant. Bold lines indicate the basic life cycle; dashed lines indicate that the specifics are unknown for this taxon. The diagram lacks specific details about survivorship between life history stages due to the lack of demographic studies or greenhouse observations on *I. spicata* ssp. *robruthiorum*. Information used to construct the life history diagram has been inferred from what we know about other members of the genus.

Because the taxon reproduces from seed, the production and germination of seeds and the survival and establishment of seedlings are likely to be critical to its long-term survival. No study has investigated the potential predation of *Ipomopsis spicata* ssp. *robruthiorum* by herbivores or the natural mortality of seed from the seed bank. For many species, the highest rate of mortality often takes place between seed placement in the seed bank and the growth of the first cohort of vegetative plants (Baskin and Baskin 2001). The relatively large size of the seeds may play an important role in the survival of the taxon. The larger the seed, the more compounds may be stored for development of new plants (Baskin and Baskin 2001). It is unknown how long the seeds of *I. spicata* ssp. *robruthiorum* can remain dormant in the seed bank before germinating. Seeds of *Phlox drummondii* can remain dormant in the soil until environmental conditions are favorable for germination (Carpenter et al. 1993). Seed viability and germination rates may also vary annually because the plant's ability to produce viable seed may be affected by varying climatic conditions (Baskin and Baskin 2001). Because the germination rate and establishment success of many native forb species are low (Baskin and Baskin 2001), and because the observed germination rate of

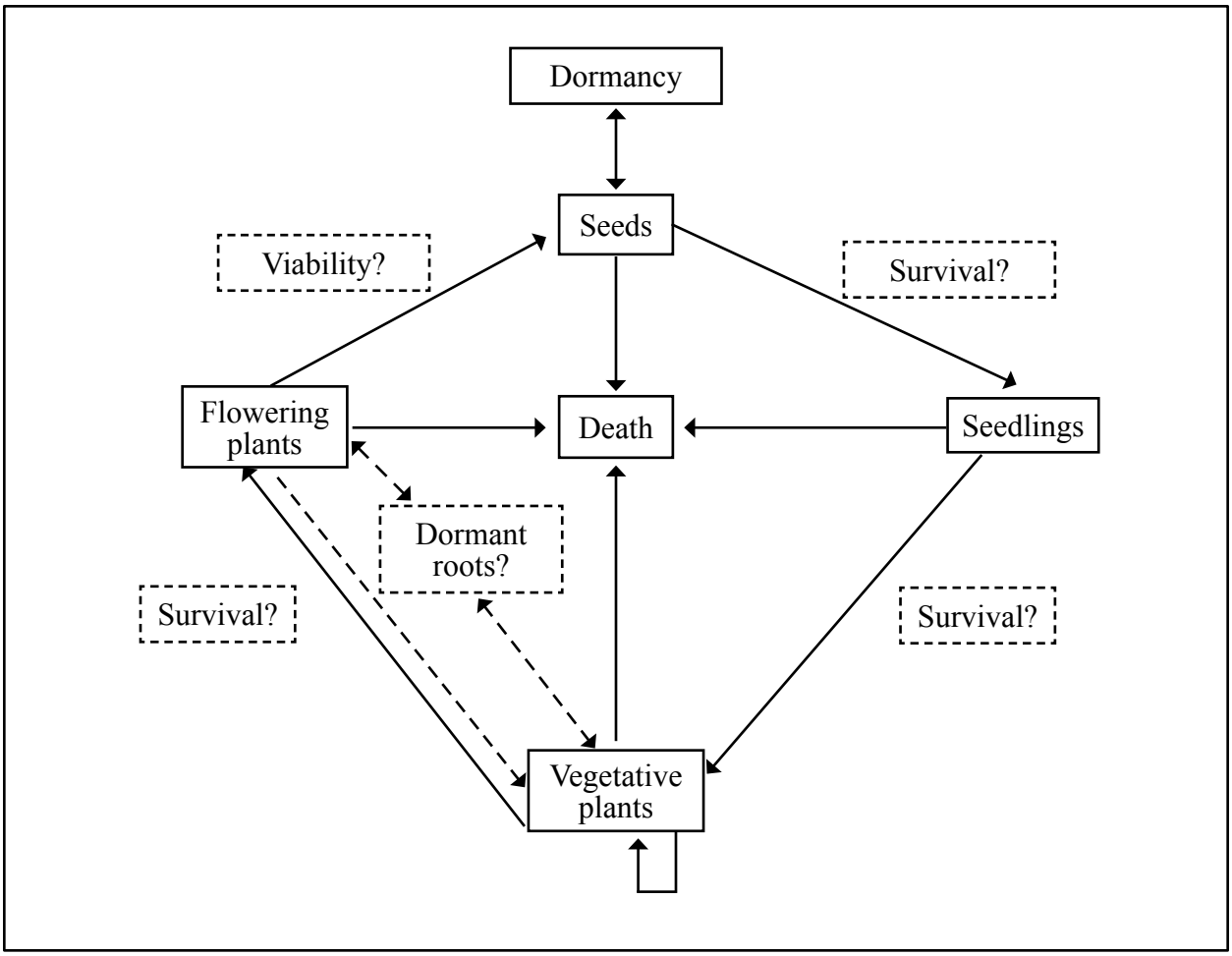


Figure 4. Life cycle diagram for *Ipomopsis spicata* ssp. *robruthiorum*. Dashed lines indicate uncertainties.

another *Ipomopsis* species (e.g., *I. polyantha*) was less than 20 percent (Collins 1995), *I. spicata* ssp. *robruthiorum* may have low seed germination and seedling establishment rates.

No studies have documented the survival of *Ipomopsis spicata* ssp. *robruthiorum* seedlings to the vegetative rosette stage or from the rosette to the flowering stage. Studies on *I. polyantha* found that the survival success of seedlings to flowering adults was 93 percent under greenhouse conditions (Collins 1995). When exposed to environmental stresses, *I. polyantha*'s survival is probably lower. Survival and growth rates of *I. spicata* ssp. *robruthiorum* will depend on the availability of resources (light, water, nutrients) in its environment and on protection from potential threats. Like other alpine taxa, it is likely that *I. spicata* ssp. *robruthiorum* is able to persist in the vegetative rosette stage for multiple growing seasons, flowering only during years with favorable climatic conditions. It is unknown whether the roots can survive in the soil from year to year without growing when environmental conditions are unfavorable for growth.

Some members of the genus *Ipomopsis* are monocarpic. For example, *I. polyantha* and *I. aggregata* produce seed once and then die (Anderson 1988, Wilken 1996, Anderson 2004). Monocarpic perennials also tend to have relatively short life spans, leading to a rapid turnover rate of aboveground individuals in the population. The population's survival depends on seed viability and persistence of the seed in the seed bank. A dashed line from flowering plants to vegetative plants is used in the life history diagram (**Figure 4**) because no studies have examined whether *I. spicata* ssp. *robruthiorum* is monocarpic. Successful seed set depends on the availability of resources needed for pollen and ovule production, embryo development, and the availability and success of pollinators. If environmental conditions are not favorable, the plants may not flower, or they may flower but not have enough resources to produce viable seeds. Similar to *I. spicata*

var. *spicata* and *I. spicata* var. *orchidacea*, *I. spicata* ssp. *robruthiorum* may also have multiple vegetative rosettes that continue to live even after the reproductive one dies (Wilken personal communication 2004).

Population viability analysis

No analyses of population viability have been documented for *Ipomopsis spicata* ssp. *robruthiorum* or for any *Ipomopsis* species. Before a population viability analysis (PVA) can be conducted for this taxon, demographic parameters (e.g., seed germination rate, survival of plants in all life stages, etc.) will need to be quantified. Information typically included in PVAs includes elements of environmental uncertainty, demographic uncertainty, and genetic uncertainties (Shaffer 1981). Environmental uncertainties range from unpredictable changes in weather patterns to unpredictable changes in the biotic community. Demographic uncertainties relate to the variation in survival and reproductive ability of the taxon (discussed above). Genetic uncertainties are associated with changes in the genetic structure of populations. The potential influences of these uncertainties on *I. spicata* ssp. *robruthiorum* will be discussed in the following paragraphs. However, with no supporting data for this taxon, no conclusions can be drawn.

Environmental uncertainties associated with the survival of the taxon include unpredictable changes in weather and climate, such as variable precipitation and global warming. The environment could also be altered by changes in community biotic composition that could increase or decrease the amount of light, moisture, and nutrients available. Variations in the environment might, in turn, affect the likelihood of survival and the fecundity of *Ipomopsis spicata* ssp. *robruthiorum*. The occurrence and distribution of natural disturbances such as wildfire and rock-slides also could affect the viability and survival of *I. spicata* ssp. *robruthiorum*. Because the influences of ecological factors (temperature, moisture, substrate type, nutrient availability, etc.) on *I. spicata* ssp. *robruthiorum* are not fully known, it is difficult to estimate the effects of environmental change, including the timing, frequency, and intensity of natural disturbances, on this taxon. Research is needed to investigate the effects of environmental change on the long-term persistence of this taxon. An international group of scientists recently has initiated a project to investigate the long-term effects of global warming on alpine plants and their habitats. This project, the Global Observation Research Initiative in Alpine Environments (GLORIA Project 2004) will provide information of the type that is needed to improve our understanding of the potential responses of *I. spicata* ssp. *robruthiorum* to global warming.

Genetic factors that could affect the survival of *Ipomopsis spicata* ssp. *robruthiorum* include inbreeding, genetic drift, and outbreeding depression. In small, isolated populations, genetic drift can be a dominant influence and can decrease genetic variability and increase a population's risk of local extinction (Barret and Kohn 1991). Decreased fitness and increased mortality were found to be higher in small, isolated populations of *I. aggregata* than in larger populations with more gene flow (Heschel and Paige 1995). Another consequence of small population size is inbreeding, which can cause loss of fitness and outbreeding depression, which is the fitness decline resulting from hybridization. Because *I. spicata* ssp. *robruthiorum* has small population sizes and habitat that is sparsely distributed across the landscape, it is possible that genetic diversity is being lost within local populations. The potential for loss of genetic diversity and limited gene flow between fragmented populations are primary threats to the long-term survival of this taxon.

Community ecology

Ipomopsis spicata ssp. *robruthiorum* is found in a wide variety of vegetation types including alpine, subalpine, and montane forests; alpine meadows, tundra, scree or talus slopes, bunchgrass communities; and cushion plant communities. The high elevation habitat of *I. spicata* ssp. *robruthiorum* is relatively remote and discontinuous across the landscape, and it tends to support plant communities with an average vegetative cover of 5 to 40 percent. Community ecology factors, including interspecific and intraspecific competition, predation and parasitism, disease, toxic or allelopathic interactions, and mutualistic interactions, have not been studied quantitatively for *I. spicata* ssp. *robruthiorum*. Much of what is known of the taxon's community ecology comes from incomplete observational notes.

An envirogram is a graphic representation of the environmental components that influence the condition of a species and affect its chance of reproduction and survival (Andrewartha and Birch 1984). In constructing an envirogram, environmental components that directly impact the species make up the centrum, and the indirect components comprise the web. When a component of the environment influences the species through an intermediate link or links, it is placed in the web. Three components of a typical envirogram are resources, malentities, and predators. Constructing an envirogram to assess directly acting components of the

environment can help resource managers answer two questions: 1) does the species chance of survival and reproduction increase or decrease as the environmental component increases?, and 2) does the abundance of the environmental component increase or decrease as the population increases? (Andrewartha and Birch 1984).

Community ecology data needed to construct a comprehensive envirogram of *Ipomopsis spicata* ssp. *robruthiorum* are unavailable. However, an envirogram for the taxon has been constructed from elements that could possibly affect the taxon directly and indirectly (**Figure 5**). The bold lines refer to factors for which some evidence of impact exists. Dashed lines refer to factors whose effects are more speculative. This envirogram should be interpreted cautiously. Inferences must be tested before using this envirogram to predict responses to management actions. Resources for *I. spicata* ssp. *robruthiorum* include soil nutrients and water for growth and reproduction requirements, pollinators for reproduction requirements, and seed dispersal for population persistence. Environmental malentities include competition from other species; trampling; and depletion of pollinators, the seed bank, and/or the depletion of the taxon directly.

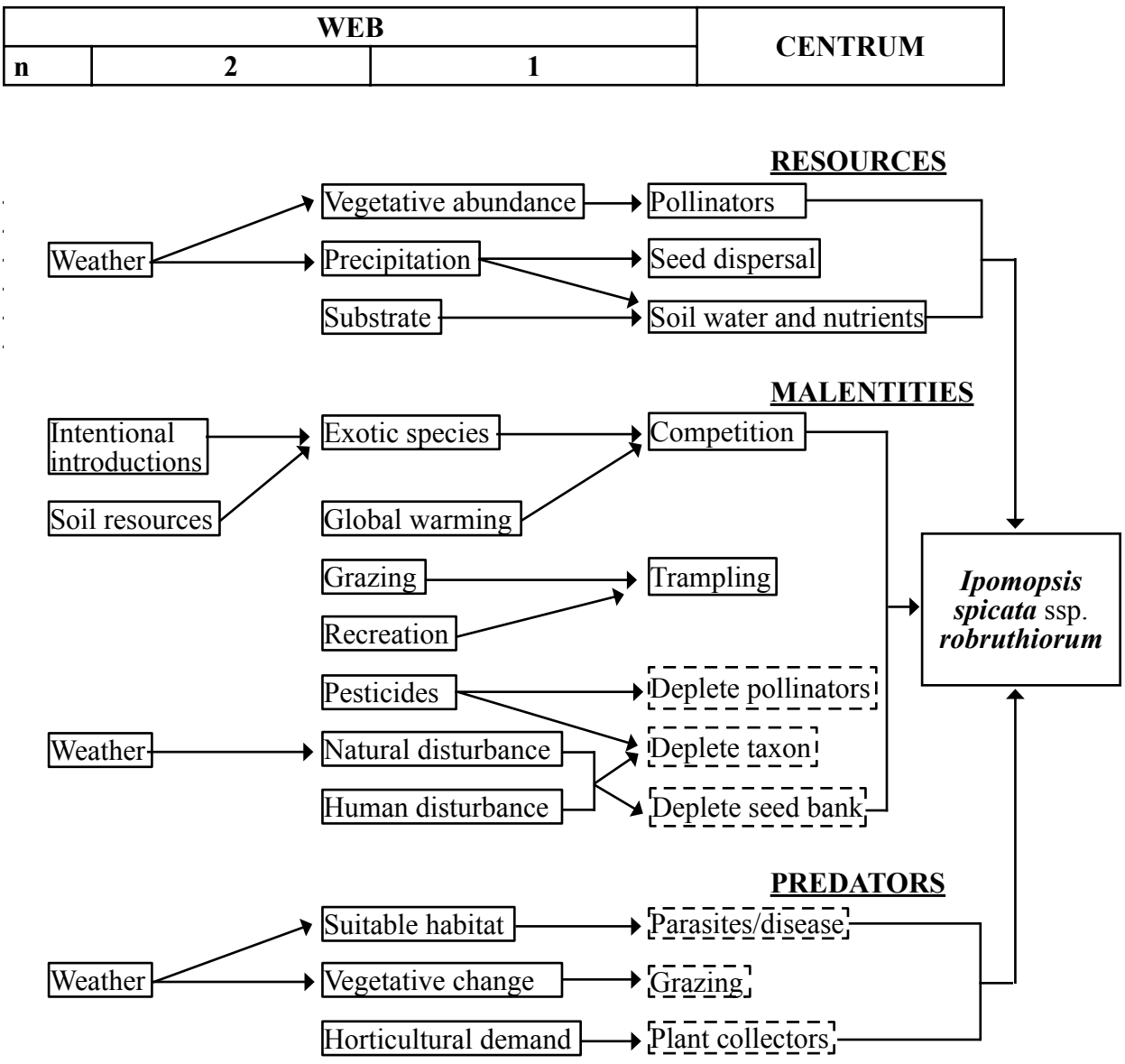


Figure 5. Envirogram of *Ipomopsis spicata* ssp. *robruthiorum*.

Habitat influences

The ridges and other open, high elevation habitats where *Ipomopsis spicata* ssp. *robruthiorum* occurs can exhibit variable climatic and substrate conditions that may affect the taxon's survival both positively and negatively. The amount of precipitation and the quality of substrate determine the amount of nutrients present in the soil and the rate of nutrient uptake. *Ipomopsis spicata* ssp. *robruthiorum* grows on fine soils and clay-rich gravelly substrates derived from andesite (Welp et al. 2000). The texture (sand, silt, clay) of the substrate will determine if nutrients and minerals are tightly bound to the substrate or if they are available for plant uptake. The porosity of the soil substrate and the availability of water will also determine if nutrients and minerals are mobile and available for plant uptake. In favorable climatic years, nutrients and minerals may be readily available. In drought years, nutrient immobility may prohibit plants from acquiring essential resources for seed production and seedling survival.

Environmental forces also shape the biotic community and vegetative abundance of *Ipomopsis spicata* ssp. *robruthiorum*'s habitat and ultimately contribute to its distribution and abundance, as well as the distribution and abundance of its pollinators. Vegetative community composition and vegetative abundance fluctuate with environmental factors such as climate change and natural disturbances. It is unknown if natural (fire) or anthropogenic (timber harvest, mining) disturbances to the environment affect the plant's abundance, its pollinator abundance, or its seed bank. The specifics of *I. spicata* ssp. *robruthiorum*'s relationship to its environment, and the disturbances in that environment, have yet to be studied.

Competition

The competitive relationships of *Ipomopsis spicata* ssp. *robruthiorum* have not been studied. Exotic invasive plants grow in the vicinity of *I. spicata* ssp. *robruthiorum*'s habitat and, in some cases, grow with the taxon (see Threats section). Exotic plants increase competition for resources, displace native species, and may threaten this taxon.

Predation, parasitism, and disease

Potential predators include grazers and plant collectors. It is not known if *Ipomopsis spicata* ssp. *robruthiorum* is palatable to grazing livestock, wildlife, or insects, or if it has evolved mechanisms to avoid being grazed. The taxon is found in active grazing allotments, but grazing is considered to be a low-level threat because no evidence of grazing by herbivores has been recorded for *I. spicata* ssp. *robruthiorum*. Studies of *I. aggregata* indicate that grazing may promote overcompensation and increased reproductive output (Paige 1999). Other grazing studies on *I. aggregata* found no overcompensation, but they did find that grazing negatively impacted the species and caused reduced fitness (Jenger and Bergelson 2000). Heschel and Paige (1995) found that the negative effects of simulated grazing on *I. aggregata* increased as population size decreased. It is unknown how the results of these studies of *I. aggregata* apply to *I. spicata* ssp. *robruthiorum*.

Persons who are interested in horticultural use of the taxon are also a potential threat to *Ipomopsis spicata* ssp. *robruthiorum* if they deplete the soil seed bank or remove whole plants. Parasites and diseases are additional potential malentities; these have not been studied for this taxon. Herbarium specimen data have not noted parasites or disease.

Mutualistic interactions

No studies or observations on symbiotic or mutualistic interactions of *Ipomopsis spicata* ssp. *robruthiorum* have been completed. It is possible that mutualistic associations exist to aid the uptake or production of nutrients. Arbuscular mycorrhizal (AM) fungi are found in the genus *Gilia* and may be present in *I. spicata* ssp. *robruthiorum* (Cripps personal communication 2003). Two thirds of recently examined alpine plants from the Shoshone National Forest were found to be mycorrhizal (Cripps personal communication 2003). Although *I. spicata* ssp. *robruthiorum* was not examined, it is probably endomycorrhizal (Cripps personal communication 2003).

CONSERVATION

Threats

Currently, so little is know about *Ipomopsis spicata* ssp. *robruthiorum* that threats to this taxon are not well-understood. The discussion of threats in this document is based mainly on conversations with USFS biologists and on the biological and habitat characteristics of the taxon that increase its vulnerability to reductions in abundance and distribution, such as its limited range, small isolated populations, and the climatic variability of its habitat.

Global warming and genetic uncertainties are the primary threats to *Ipomopsis spicata* ssp. *robruthiorum*. Average temperatures in Wyoming have increased 1.5 °F in the last century and are predicted to increase another 5 °F by 2100 (U.S. Environmental Protection Agency 1998). The amount and timing of precipitation patterns are also predicted to change in Wyoming by 2100. Climatic changes from global warming may impact nutrient cycling, plant reproductive patterns, and a myriad of other ecosystem factors. Increased temperatures may cause shifts in plant community dynamics and may broaden, raise, or decrease the range of elevations at which specific plant species can survive. Global warming may also shift the plant community structure and composition in Wyoming, which, in turn, may affect competitive relationships. For *I. spicata* ssp. *robruthiorum*, global warming may cause increased vegetative cover and competition in the subalpine and alpine zones and/or a reduction in suitable habitat. Global warming could also cause the alpine zone to disappear, resulting in local extirpations of alpine species (U.S. Environmental Protection Agency 1998), including *I. spicata* ssp. *robruthiorum*. Currently, the scope of the potential rangewide impacts to *I. spicata* ssp. *robruthiorum* from global warming is unknown. Results from the GLORIA Project (2004), which is investigating the impacts of global warming, are expected to provide valuable data that can be used in the future to improve conservation of taxa such as *I. spicata* ssp. *robruthiorum*.

Genetic factors that could affect the survival of *Ipomopsis spicata* ssp. *robruthiorum* include inbreeding, genetic drift, and outbreeding depression. In the small, isolated occurrences of *I. spicata* ssp. *robruthiorum*, genetic drift could be a dominant influence and could decrease genetic variability and increase the population's risk of local extinction (Barret and Kohn 1991). Small populations are also more subject to inbreeding, which can cause loss of fitness, and to outbreeding depression, which is the fitness decline resulting from hybridization. Because *I. spicata* ssp. *robruthiorum* has relatively small population sizes and isolated occurrences, low genetic diversity could be a primary threat. Research is needed to determine the significance of this potential threat.

All 16 known occurrences of *Ipomopsis spicata* ssp. *robruthiorum* are located on National Forest System lands. Two occurrences are on land managed for multiple use, and 14 occurrences are on land managed for wilderness. Wilderness status ensures that wilderness areas are protected from motorized vehicles and are managed to preserve natural conditions (Wilderness Act 16 U.S.C. 1 1 21). However, because the wilderness area regulations do not call specifically for protection of *I. spicata* ssp. *robruthiorum*, this designation only implies and does not guarantee its protection.

Recreational use by hikers, horseback riders, ATV users, and campers occurs in the vicinity of *Ipomopsis spicata* ssp. *robruthiorum* and poses a moderate threat from trampling. These plants may not be able to tolerate high levels of trampling for prolonged or constant periods. Threats of trampling are especially noticeable for the occurrence near Windy Mountain (occurrence 6, **Table 3** and **Table 4**), which is adjacent to a hiking trail. In the past, the Shoshone National Forest ecologist has worked closely with trail crews to avoid known occurrences in order to minimize threats from trail construction and recreation (Houston personal communication 2003). ATV use on the forest is restricted to specific roads and trails by the Shoshone National Forest Travel Plan. However, illegal off-road travel by ATVs is a threat to an occurrence near Carter Mountain (occurrence 8, **Table 3** and **Table 4**). Another potential threat is the harvest of the plants by plant collectors seeking plants for rock gardens. *Ipomopsis spicata* is used as a rock garden species and is grown and sold commercially (Rock Garden Plant Database 2002). Although *I. spicata* ssp. *robruthiorum* has not been sold commercially, it is possible that it could become commercially important in the future.

The spread of exotic invasive species is a moderate threat to *Ipomopsis spicata* ssp. *robruthiorum*. Exotic species such as Dalmatian toadflax (*Linaria dalmatica*), spotted knapweed (*Centaurea maculosa*), diffuse knapweed (*C. diffusa*), and oxeye daisy (*Chrysanthemum leucanthemum*) are present in the Absaroka Mountains. These exotics can increase resource competition and displace native plants (Sheley and Petroff 1999). While these exotic species have not been found growing with *I. spicata* ssp. *robruthiorum*, they have been observed at high elevations in the Absaroka Mountains and have the potential to spread and threaten *I. spicata* ssp. *robruthiorum* populations. *Linaria dalmatica* and *Centaurea maculosa* grow in the proposed Grizzly Creek RNA and could threaten *I. spicata* ssp. *robruthiorum* on the dry ridges (Houston personal communication 2003). Other potentially threatening exotic plant species include cheatgrass (*Bromus tectorum*), which grows in habitats where *I. spicata* ssp. *robruthiorum* may also exist, including grasslands, shrublands, and Douglas-fir forests. *Poa pratensis* (Kentucky bluegrass) and *Cirsium arvense* (Canada thistle) occur in riparian zones (Jones and Fertig 1999) and could impact *I. spicata* ssp.

robruthiorum along the tributary washes. One exotic plant, *Melilotus officinalis*, is known to grow with *I. spicata* ssp. *robruthiorum* (Fertig 1997a), but its impacts on the taxon have not been studied. Some burned areas near *I. spicata* ssp. *robruthiorum* occurrences have been reseeded with the exotic grasses smooth brome (*B. inermis*) and meadow timothy (*Phleum pratense*) (Jones and Fertig 1999). These species could spread and pose potential threats of increased competition and displacement. Management of invasive species poses another low-level threat to the taxon. Pesticides used in the vicinity of *I. spicata* ssp. *robruthiorum* to control invasive plants or insect pests could impact plants and/or pollinators through direct contact or pesticide drift.

Ipomopsis spicata ssp. *robruthiorum* occurs in active livestock grazing allotments on the forest, but current grazing levels appear to be a low-level threat for the taxon because no direct grazing of *I. spicata* ssp. *robruthiorum* has been noted. However, grazing or trampling by herbivores is a threat that has never been studied, and it is not known if *I. spicata* ssp. *robruthiorum* is palatable to livestock (Fertig et al. 1994, Fertig 1995, Fertig 2000, Handley et al. 2002). Livestock grazing is permitted on National Forest System lands, including wilderness areas. The high elevation habitat where the taxon is found has low vegetative productivity and is not heavily used by livestock, thus reducing the risk of grazing or trampling threats. Further reducing the threat of grazing, most sheep allotments on the forest are currently vacant, and the remaining sheep herds are being moved off the forest due to predator conflicts (Houston personal communication 2003). Refraining from using grazing allotments until the late summer when the taxon has completed its lifecycle could further minimize livestock grazing and/or trampling threats. Wildlife that graze at high elevations may pose a threat of trampling to the taxon. A better understanding of the impacts of grazing by wildlife on *I. spicata* ssp. *robruthiorum* is needed for the conservation of this taxon.

Mineral development on USFS lands is not restricted due to the presence of *Ipomopsis spicata* ssp. *robruthiorum*. Mines are present on National Forest System lands outside the wilderness areas, near occurrences of *I. spicata* ssp. *robruthiorum*. These mines currently have minimal activity and are a low-level threat to the taxon at the present time. The taxon could be impacted by mining activities on the mountain slopes if the mining activity becomes more active and/or if roads or new mines are developed in the area. Management by the Shoshone National Forest has minimized threats of mines to species of concern through land swaps with mine owners (Houston personal communication 2003). Mines near the forest boundary that remain in private ownership also are currently inactive and pose a low-level threat to *I. spicata* ssp. *robruthiorum* at the present time.

Timber harvest, wildfire, and fire management occur on USFS lands. If and how the frequency, intensity, and timing of these activities directly or indirectly affect *Ipomopsis spicata* ssp. *robruthiorum* has never been formally studied. However, the level of threat from these disturbances can be speculated upon based on the taxon's habitat. The 14 occurrences in wilderness areas are not threatened by timber harvest. Outside the wilderness area, the high elevation, open canopy cover of *Pseudotsuga menziesii*, *Pinus albicaulis*, *P. flexilis*, and *Juniperus scopulorum* forests with which *I. spicata* ssp. *robruthiorum* is associated are not conducive to large-scale timber harvests. There are no active timber sale projects in *I. spicata* ssp. *robruthiorum* habitat now, and it is unlikely that timber sales will occur in the taxon's habitat in the future (Houston personal communication 2003). Therefore, threats from timber harvest activities are likely to remain low. Wildfire does occur in the taxon's habitat; for example, wildfires in 1988 burned into alpine areas of the Shoshone National Forest. However, the sites where *I. spicata* ssp. *robruthiorum* are found have low productivity and do not carry fire well, so fires are infrequent in these sites (Houston personal communication 2003). It is unknown how fire affects the taxon because no known occurrence has been subjected to a wildfire or a prescribed fire in recent times. Depending on its intensity, a fire could burn the aboveground biomass but not affect the roots or deplete the seed bank. Most fire management occurs in forest zones lower in elevation than *I. spicata* ssp. *robruthiorum* occurrences. Given the above information on fire, the level of threat from fire is expected to be low (Houston personal communication 2003).

In general, the greatest threats to small occurrences of endemic species such as *Ipomopsis spicata* ssp. *robruthiorum* may be deterministic and stochastic events (i.e., climate/habitat change and/or increases in exotic species) that could reduce the number of individuals below a critical threshold for survival (Maschinski 2000). Information on direct and indirect impacts from recreation, grazing, timber harvest, fire, invasive species, genetic uncertainties and global warming is needed in order to develop an effective long-term conservation strategy for this taxon.

Conservation Status of the Taxon in Region 2

There are currently no federal or USFS Region 2 conservation strategies for *Ipomopsis spicata* ssp. *robruthiorum*. Occurrences of this taxon within the Washakie and North Absaroka wilderness areas are protected from motorized vehicles, but they are not necessarily protected from other threats. The occurrence within the proposed Grizzly Creek RNA may receive additional protection because the primary objective of an RNA is to "... preserve a wide spectrum of pristine representative areas that typify important forest, shrubland, grassland, alpine, aquatic, geologic, and similar natural situations" (Jones and Fertig 1999). One of the specific objectives of the proposed Grizzly Creek RNA is to protect elements of biological diversity. Therefore, designating Grizzly Creek as an RNA would likely provide additional indirect protection to *I. spicata* ssp. *robruthiorum*.

There is no evidence that the distribution or abundance of *Ipomopsis spicata* ssp. *robruthiorum* is either declining or increasing in Region 2. All 16 known occurrences are located on lands managed by the Shoshone National Forest. Previously unknown occurrences of *I. spicata* ssp. *robruthiorum* have been found as recently as 1997 (Fertig 2000, Handley et al. 2002). It is possible that more occurrences exist in the large tracts of suitable habitat that are relatively unexplored. It is difficult to determine how much suitable habitat might exist because the taxon can occur in a variety of community types, including scree or talus slopes, alpine, subalpine and montane forests, tundra, bunchgrass communities, and cushion plant communities. It is also likely that habitats vary in their ability to support *I. spicata* ssp. *robruthiorum*, either on an annual or seasonal basis, due largely to variations in weather patterns and competition from other plant species. Climatic variation may make it more difficult to assess population trend and the effectiveness of current and future management. Determining whether more occurrences of *I. spicata* ssp. *robruthiorum* do exist will be necessary to decide upon appropriate management and conservation activities.

Occurrences of *Ipomopsis spicata* ssp. *robruthiorum* are subject to occasional natural or human-imposed disturbances. No studies have examined how disturbance type (e.g., fire, timber harvest, trampling), disturbance intensity (high, medium, low), and disturbance timing (season) benefit or impair the taxon. Information on the taxon's response to the timing, type, and intensity of disturbance is critical to assessing the implications of current and future management decisions on the survival of *I. spicata* ssp. *robruthiorum*. Additionally, the life-history, reproductive biology, demography, and community ecology need to be studied to determine how vulnerable the taxon is to habitat or environmental change and to demographic or environmental stochasticity. Current management activities are intended to avoid direct impacts to *I. spicata* ssp. *robruthiorum*, but they do not guarantee its future persistence. Due to our lack of knowledge of this taxon, it is not possible to say whether occurrences of *I. spicata* ssp. *robruthiorum* are secure.

Potential Management of the Taxon in Region 2

Implications and potential conservation elements

Ipomopsis spicata ssp. *robruthiorum* is endemic to the Absaroka Mountain Range of Park and Hot Springs counties in northwestern Wyoming. Management plans for these areas have not specifically addressed this taxon.

Ipomopsis spicata ssp. *robruthiorum* exhibits characteristics of species that can tolerate low levels or short durations of stress but may not be able to recover from high levels or prolonged durations of stress. For example, the taxon may be able to tolerate low level, short duration stresses such as occasional trampling caused by recreational hikers but may not be able to tolerate higher levels of stress caused by soil-disturbing vehicles. There have been no quantitative or observational studies of this taxon, so the effects of environmental changes from natural or man-made disturbances on the abundance, distribution, and persistence of *I. spicata* ssp. *robruthiorum* are unknown. If land managers are to be successful in the future conservation of *I. spicata* ssp. *robruthiorum*, they must acquire the best biological information attainable and be willing and able to seek imaginative and creative solutions (Fay 1981). A critical prerequisite for conservation of sensitive species is to conduct inventories and long-term monitoring to determine population trends, and whether these trends are a result of natural or human-caused habitat alterations (Davy and Jefferies 1981). The current lack of information on the response of *I. spicata* ssp. *robruthiorum* to changes of any kind makes it difficult to describe with confidence the effects of historic, current, or future management. Monitoring will be necessary to determine if natural (fire, grazing) or human-caused (timber harvest, grazing,

mining, recreation) disturbances affect population size and persistence.

Most management strategies for sensitive species are based on an understanding of the demographic features of the species (local population sizes and growth rates) and the requirements for habitat preservation. An increased knowledge of *Ipomopsis spicata* ssp. *robruthiorum*'s demographic parameters, gained through future survey and monitoring efforts (outlined below), will be needed to provide a better foundation for the conservation of *I. spicata* ssp. *robruthiorum*. Habitat preservation through the establishment of additional special land use designations (wilderness, RNA) during the forest's land use planning activities could benefit for *I. spicata* ssp. *robruthiorum* if it is determined that the taxon could be directly or indirectly impacted by motorized disturbance (Robinson et al. 1981). While habitat preservation can provide some conservation protection, it does not ensure protection from fluctuating environmental factors (i.e., global warming, pollinator availability, trampling, and invasive species) that may reduce the habitat's ability to support a viable population. Habitat preservation also does not guarantee that the taxon will continue to exist even if the habitat has not changed. Habitat preservation can, however, provide opportunities for biological and ecological studies that would greatly aid in our understanding of this taxon.

In addition to habitat preservation, strategies to maintain *Ipomopsis spicata* ssp. *robruthiorum*'s genetic variation are important to management and conservation planning. Genetic variation increases a species' ability to adapt to environmental changes and decreases its susceptibility to pests and disease (Barret and Kohn 1991). Some sensitive species have genetic differentiation between occurrences while others do not (Karron 1991). Without any current data on the genetic variability of *I. spicata* ssp. *robruthiorum*, it is difficult to make generalizations on the number of plants needed to maintain viable populations. In general, management aimed at maintaining large population sizes may preserve genetic diversity by reducing the effects of inbreeding and genetic drift (Barret and Kohn 1991). Studies of genetic variation within and between occurrences could be important for determining the population size needed to preserve genetic diversity. Studies of genetic variation also help in determining if management should focus primarily on habitat preservation or if manipulation of genetic resources is important for the long-term survival of the taxon.

Insect pollinators of *Ipomopsis spicata* ssp. *robruthiorum* have yet to be identified. Identification of these species should be a primary research goal. If it is determined that this taxon requires pollination for seed set, then conservation programs should include protection of essential pollinator populations and their habitat. Protecting essential pollinators could include decreasing the use of pesticides that affect insect pollinators and protecting pollinator habitats (e.g., hives, nests).

Tools and practices

Species inventory

Relatively little information has been collected for this taxon. Several portions of the Absaroka Mountains have been systematically surveyed for floristic diversity (Rosenthal 1999) and for target species of concern (Mills and Fertig 1996, Fertig 1997b). For example, the one and a half month survey conducted by Fertig in 1997 covered large portions of the Shoshone National Forest for 17 species listed as sensitive. A total of 46 plant species of concern were located, including one occurrence of *Ipomopsis spicata* ssp. *robruthiorum*. While many areas in the Shoshone National Forest have been surveyed, comprehensive surveys of alpine areas, the Washakie Wilderness, and a rangewide survey focusing particularly on *I. spicata* ssp. *robruthiorum* are lacking. There is a potential for locating additional occurrences and gaining knowledge about *I. spicata* ssp. *robruthiorum* if a thorough survey of the known and potential range is conducted. The Shoshone National Forest has no planned inventory or monitoring surveys for *I. spicata* ssp. *robruthiorum* in the near future (Houston personal communication 2003).

The USFS provides employees with the Wyoming Rare Plant Field Guide (Fertig et al. 1994) to assist them in identifying rare, sensitive, and endemic plants. Additionally, a field guide to the rare and sensitive plants of the Shoshone National Forest (Mills and Fertig 1996) is available to USFS employees. These guides include identification information and habitat descriptions to help employees locate rare, sensitive, endemic, threatened, and endangered plants. The Shoshone National Forest does not have the funding necessary to teach all field employees sensitive plant identification (Houston personal communication 2003), and the amount of surveying employees can accomplish is low because of other work priorities. Encouraging greater use of field guides and allowing more time

for Shoshone National Forest employees to conduct sensitive plant surveys are two means of identifying potential new occurrences of species of concern, which could later be verified by the forest botanist. However, surveys by field crews are not a replacement for more thorough and focused surveys by trained botanists.

Location data for *Ipomopsis spicata* ssp. *robruthiorum* occurrences are inconsistent and lack detail (**Table 3** and **Table 4**). A Geographic Positioning System (GPS) unit can record the exact geographic locations of occurrences, making it a critical mapping and monitoring tool. While surveying an area, a GPS unit can also be used to collect "non-feature points," in essence, creating a map of the area that the surveyor has covered, whether or not rare plant occurrences are found. Accurate mapping of the area surveyed helps to prevent surveyors from duplicating search efforts. Mapping areas where the sensitive taxon was not found can also help to delimit areas of suitable habitat, which can help to focus future surveys. A GPS data dictionary or data monitoring forms can be used to consistently describe detailed information about a taxon's occurrences. To learn more about the taxon's population size, biology, and community ecology, all of the following examples could be included in an inventory for *I. spicata* ssp. *robruthiorum*: the size of the occurrence (area covered), the number of individuals per occurrence, the habitat type occupied (microhabitat and/or surrounding habitat), unique geographic features, geologic substrate, physiognomic class of surrounding vegetation (shrubland, herbaceous, woodland, forest, etc.), and/or canopy cover. Gathering site data can also be used to determine the taxon's spatial distribution within potential habitat. Inventories must be conducted when the taxon is flowering to ensure that it is correctly identified. If the occurrence is large, a voucher specimen should be taken. The importance of collecting comprehensive occurrence and ecological documentation on this taxon cannot be over-emphasized.

Habitat inventory

There has been one known habitat inventory for this species. The Shoshone National Forest, Wyoming Natural Diversity Database botanists, and Jones and Fertig (1999) inventoried and evaluated habitat and, as a result, designed an RNA around known locations of several sensitive and rare plants, including one occurrence of *Ipomopsis spicata* ssp. *robruthiorum* (Houston personal communication 2003).

Existing habitat information for this taxon is not detailed (**Table 4**). Some element occurrence records include descriptions of the taxon's habitat and associated species. However, the majority lack detailed habitat descriptions. The existing habitat descriptions in occurrence records suggest that this taxon grows in a variety of habitats. A thorough inventory of *Ipomopsis spicata* ssp. *robruthiorum*'s known occurrences has not been conducted. A thorough habitat inventory could provide important information on the taxon's habitat requirements and on environmental changes that could impact this taxon. This information will increase our ability to protect the taxon. There are no studies that relate the abundance or vigor of occurrences to habitat conditions or habitat disturbance. The characteristics of potential habitat are not well understood, making it difficult to identify areas that could be colonized by this taxon or that could contain additional *I. spicata* occurrences.

Population monitoring

No formal monitoring or demographic studies for *Ipomopsis spicata* ssp. *robruthiorum* have been conducted nor are any planned. Only two of the known occurrences of *Ipomopsis spicata* ssp. *robruthiorum* have been revisited since they were first discovered (occurrences 1 and 9 in **Table 3**; Wyoming Natural Diversity Database 2002). Information on population size or vigor has not been recorded. Science-based, long-term monitoring would improve our knowledge of the life cycle, community ecology, biology, and demography of this taxon and its population trends and conservation needs. Long-term monitoring is also valuable for assessing the influence of climatic and biotic interactions (Davy and Jefferies 1981) and population size fluctuations (Primack 1998). For evaluating population change over time, the use of permanent monitoring plots or transects is recommended (Elzinga et al. 1998). Techniques used for monitoring will depend on the monitoring goals. Monitoring of *I. spicata* ssp. *robruthiorum* may include counting the number of individual plants at each occurrence site; recording the phenological stage, and whether seeds appear to be formed; and sketching, measuring, and/or marking (flags or tags) each plant's location in relation to others and nearby topographic features (Elzinga et al. 1998, Primack 1998). By marking the location of individual plants, researchers can determine whether plants are dormant or deceased (Lesica 1994). Marking locations may include the use of GPS units, maps, compasses,

and tape-measures. More intensive sampling requires that recruitment (seedling establishment), losses (mortality), reproductive success, and dispersal strategy be recorded (Davy and Jefferies 1981). Monitoring surveys could record the size and reproductive status of each plant, flower production (i.e. fruit, no fruit, predation), and fecundity (number of mature fruit), to contribute to the demographic information on *I. spicata* ssp. *robruthiorum*. In years when fruit production is adequate, a predetermined number of fruits could be collected from a predetermined number of plants. The number of seeds could be counted, insect predation noted, and a germination viability test performed on the seeds. This data can be analyzed in stage-structure transition matrix projection models to summarize how survival, growth, and reproduction at various life-history stages interact to determine population growth (Lesica 1994). Monitoring will be most effective if performed when *I. spicata* ssp. *robruthiorum* can be easily identified, which is in the flowering stage.

In the past decade, the WYNDD has worked in cooperation with the Shoshone National Forest and the University of Wyoming's Rocky Mountain Herbarium to revisit or discover new locations of high priority, rare plant species (Fertig 1998). The report included *Ipomopsis spicata* ssp. *robruthiorum* although it was not included in the original monitoring efforts. Ensuring that its occurrence locations are included in future site visits will improve our knowledge of the taxon and improve conservation efforts. Furthermore, establishment of a long-term monitoring program for *I. spicata* ssp. *robruthiorum* occurrences would contribute valuable information about the demographic factors contributing to population sustainability.

Ipomopsis spicata ssp. *robruthiorum*'s response to disturbances caused by management practices should be rigorously examined through monitoring. When a management action is scheduled in the plant's habitat, information on the size and state of the occurrence could be gathered one year prior to disturbance. By monitoring the population dynamics in response to disturbance, managers should be able to determine if the management practice was beneficial or detrimental. It is important to monitor the population for several years following disturbance to account for natural variation in size, for example, in response to varying weather patterns. Population trend data correlated with disturbances will be critical for designing and carrying-out future management practices in a manner that ensures persistence of the taxon.

Experimental treatments and monitoring may help to determine sustainable management practices for *Ipomopsis spicata* ssp. *robruthiorum*. One example is the use of exclosures around occurrences threatened by trampling and/or grazing. If the occurrences increase in size or density within the exclosures, then management actions that decrease the threat of trampling or grazing (e.g., rerouting trails) may promote increases in numbers of *I. spicata* ssp. *robruthiorum*. Experiments like this must be properly designed (including the use of controls), implemented, and analyzed to allow valid conclusions to be made.

Monitoring and maintaining existing levels of genetic diversity in plant populations are major issues for conservation of a species. Assessment of the current status of genetic variation can be accomplished through measuring morphological and phenotypic variation, allozyme electrophoresis, and DNA sequencing (Schall et al. 1991). This work is time consuming and expensive, but it could also be the most valuable way to determine the likelihood that the taxon will persist in the future under uncertain environmental and genetic conditions.

Habitat monitoring

Habitat monitoring for *Ipomopsis spicata* ssp. *robruthiorum* is important because the environmental conditions needed for its survival are not defined. Understanding the relationship of *I. spicata* ssp. *robruthiorum* to its habitat and habitat disturbances will help land managers to determine appropriate land use practices for ensuring the future persistence of this taxon. Thoughtful planning of sampling procedures and methods is critical to obtaining high-quality data and to assuring its usefulness (Center for Plant Conservation 1991).

Habitat monitoring in plant occurrence locations could be conducted concurrently with population monitoring. Combining population and habitat monitoring can make the work more efficient, but more importantly, it will facilitate correlation of environmental conditions with long-term population trends. A geographic information system (GIS) is an excellent tool for mapping locations and recording habitat attributes for *Ipomopsis spicata* ssp. *robruthiorum*, and it is a relatively accurate and simple method for updating and monitoring large-scale habitat change. On-the-ground habitat monitoring could also be a component of a long-term species

conservation program to monitor factors that cannot be detected from satellite imagery. These factors include associated species, canopy cover, spread of invasive plants, land use designations, impacts from land use activities, and the spread of parasites and disease. A general habitat inventory has been initiated by the Shoshone National Forest, including GPS-located plots for ecological surveys. Although these plots are not currently monitored, they provide a framework to initiate habitat monitoring for *I. spicata* ssp. *robruthiorum* in the future.

Population or habitat management approaches

There have been no systematic mapping and monitoring programs for *Ipomopsis spicata* ssp. *robruthiorum* occurrences in protected areas, and therefore the benefit of protection cannot be assessed. Current beneficial management practices that have been implemented are site-specific surveys for *I. spicata* ssp. *robruthiorum* where management activities are planned (no occurrences have been found in these areas), restriction of motorized vehicles, and avoidance of known occurrences during land management activities. Another beneficial tool is the use of field guides of sensitive plants in Wyoming and on the Shoshone National Forest to assist in the detection of new occurrences.

Long-term conservation and management of the taxon will require additional management approaches. The conservation of *Ipomopsis spicata* ssp. *robruthiorum* may involve the preservation of existing occurrences, surveying for additional occurrences, monitoring population trends and response to habitat changes, and recording information on life-history stages and demography. Studies that increase our understanding of the taxon, its environment, and its response to habitat alteration will enhance the ability of managers to develop appropriate conservation plans. Management programs that include all of the above conservation strategies are likely to be the most successful (Holsinger and Gottlieb 1991).

Information Needs

Information on the biology and management of *Ipomopsis spicata* ssp. *robruthiorum* compiled through this assessment can be used to identify knowledge gaps and to prioritize efforts to satisfy these information needs. To address these gaps, information can be obtained through surveys, monitoring, and research studies. A priority for *I. spicata* ssp. *robruthiorum* is a thorough field survey to better document the status of this taxon. This includes surveying for additional occurrence locations and monitoring population trends (Welp et al. 2000). This taxon's perceived rarity may be due to the lack of specific surveys. A survey focusing on *I. spicata* ssp. *robruthiorum* could provide additional information on the taxon's distribution and population size, possibly increase the number of known occurrences, and more rigorously define the taxon's habitat requirements. Long-term monitoring is also a priority for *I. spicata* ssp. *robruthiorum*, particularly if surveys find that the taxon is truly rare. Monitoring can provide additional information on the location, habitat, threats (e.g., disturbance, invasive species, global warming), population trends, life-history, and demography of *I. spicata* ssp. *robruthiorum*. Initiation of long-term population monitoring would also give land managers better knowledge of disturbance impacts (both natural and human-caused), the taxon's biology and community ecology, and its ability to tolerate exotic invasive species. This information is essential to developing land management strategies that protect *I. spicata* ssp. *robruthiorum*, and for evaluating a long-term protective designation. Research studies, such as a PVA or testing the taxon's response to trampling, can also provide important information for management.

There is so little known about *Ipomopsis spicata* ssp. *robruthiorum* that many research projects could be initiated. For example, pollination ecology could be examined to determine whether the species depends on specific pollinators. Research could also identify the lifecycle stages of the taxon that have the greatest influence on its growth and survival, the size of the population needed to maintain genetic diversity, and if current reproductive output is sufficient to maintain population levels. Studies could also investigate the breeding system and seed ecology of this taxon and answer questions such as whether it is self-compatible or an obligate outcrosser, whether its reproduction is limited by resource availability, and what the seed longevity is in the soil seed bank.

In summary, information needs in order of importance are:

- Surveying for new occurrences,
- Monitoring existing sites,

- Assessing habitat requirements,
- Conducting demographic studies,
- Investigating reproductive biology, and
- Studying ecological genetics.

Gaining this information is critical for conservation management and will contribute to more effective management decisions relative to the persistence of this taxon.

DEFINITIONS

Allopatric — Occurring in different places or the geographic separation of a species.

Andesite — Fine-grained volcanic rock.

Anthers — The pollen-bearing part of the flower.

Basal — At the base of the plant.

Boundary layers — The area around the leaf or root in which the conditions differ from those in the atmosphere or soil, respectively.

Caudex — The persistent base of a stem from which new stems or leaves arise at or below ground.

Category 2 (C2) — A taxa for which current information indicated that proposing to list as endangered or threatened was possible, but appropriate or substantial biological information was not on file to support an immediate rule-making.

Corolla — Petals referred to collectively.

Cytologic — The study of the microscopic appearance of cells, especially for the diagnosis of differences, abnormalities, or malignancies.

Endomicrorrhizal — A mutualistic association between a fungus and a plant root in which the fungus enters the host cells.

Filaments — The stalks that support the pollen-bearing part of the flower.

G5 — Species is demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

K-selected species — A species with high resistance to disturbance or perturbation, but once disturbed it has little capacity for recovery.

Monocarpic — A plant that dies after flowering. It may remain in the rosette stage for years before flowering.

Mycorrhizal — A mutualistic association between the roots of a plant and a fungus.

Polymorphism — The existence within a species or population of different forms of individuals, beyond those that are the result of simple mutation.

Rosette — Cluster of leaves radiating out in all directions from the stem at the base of the plant.

S2 — Imperiled in state because of rarity (6-20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

S-R species — Stress tolerant - Ruderal species. A species that tolerates environmental stresses and disturbance.

Subcapitate — Somewhat of a dense, head-like structure.

T2 — Subspecies is imperiled globally because of rarity (6-20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

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